VIKING LABS / HONEYWELL
370 BERNARDO AVENUE
MOUNTAIN VIEW, CA 94043

Model M6003 Oscilloscope

Operator's Manual

OMEGA ENGINEERING, INC.

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Printed in U.S.A.

M357/045

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Specifications
Oscilloscope M 6003
60 MHz

Operating Modes

Channel I, Channel II, Dual
Channel selection: alternate and chopped (approx. 1 MHz).
Sum and difference: Ch II ± Ch I (invertable).
X-Y mode: same sensitivity ranges.

Vertical Amplifiers (Y)

Bandwidth of both channels:
0 to 60 MHz (−3 dB), 0 to 85 MHz (−6 dB).
Rise time: approx. 5.8 ns. Overshoot: max. 1 %.
Deflection coefficients: 12 calibrated steps from 5 mV/DIV to 20 V/DIV with 1-2-5 sequence, variable 2.5:1 up to at least 50 V/DIV.
Accuracy in calibrated positions: ± 3 %.
Y-magnification X 5 (calibrated) up to **1 mV/DIV** in the frequency range from 0 to 15 MHz (−3 dB).
Input impedance: 1 MΩ II 30 pF.
Input coupling: DC-AC-GND.
Input voltage: max. 400 V (DC + peak AC).
Y-output for Ch II: 50 mV/DIV on 50 Ω.
Y-overscanning indication: with 2 LEDs.
Delay line: approx. 90 ns

Timebase

Time coefficients: 23 calibrated steps from 50 ns/DIV to 1 s/DIV with 1-2-5 sequence, variable 2.5:1 up to at least 2.5 s/DIV, with **X-magnification X 10** (± 5 %) to **5 ns/DIV.**
Accuracy in calibrated positions: ± 3 %.
Hold-off time: variable up to approx. 10:1.
Ramp output: approx. 5 V (positive-going).
Triggering: automatic to peak value or normal triggering.
With LED indication for trigger action.
Single sweep: Single-Reset pushbuttons. LED.
Slope: positive or negative-going.
Source: Ch I, Ch II, alternate, CH I/CH II, line, external.
Coupling: AC, DC, HF and NF filter.
Trigger threshold: internal 5 mm, external 50 mV.
Trigger bandwidth: 0 to at least 80 MHz.
Sweep delay: 7 decade steps from 100 ns to 0.1 s, variable approx. 10:1 to 1 s.
Modes: search, delay. (LED indication).

Horizontal Amplifiers (X)

Bandwidth: 0 to 5 MHz (−3 dB).
Input via CH II (see vertical amplifiers).
X-Y phase shift: < 3° below 100 kHz.

General Information

Component Tester
Cathode-ray tube: rectangular screen, fast warm-up, internal graticule 8 x 10 DIV (1 DIV = 9.7 mm)

rectangular screen, fast warm-up,
internal graticule 8 x 10 DIV (1 DIV = 9.7 mm).
Total acceleration voltage: 14 kV.
Graticule illumination: three-position.
Trace rotation: adjustable on front panel.
Z-modulation input: positive TTL level.
Calibrator: square-wave generator, switchable to ≈ 1 kHz and 1 MHz (t_r < 5 ns) for probe compensation.
Output voltage: 0.2 V and 2 V ± 1 %.
Electronic regulation of all operating voltages.
Protection type: protection class I (VDE 0411).

Line voltages: 110, 125, 220, 240 V AC,
Permissible line fluctuation: ± 10 %.
Line frequency range: 50 to 60 Hz.
Power consumption: approx. 40 Watts.
Weight: approx. 8 kg. Color: anthracite.
Case dimensions (mm): W 285, H 145, D 380.
With adjustable tilt handle.

Operating Instructions

General Information

The M 6003 is designed for ease of operation. The operating controls are logically arranged; the user will quickly become familiar with the operating principle of the instrument. However, even experienced operators should study these operating instructions thoroughly to prevent wrong operation and to be familiar with all criteria of the instrument for later use.

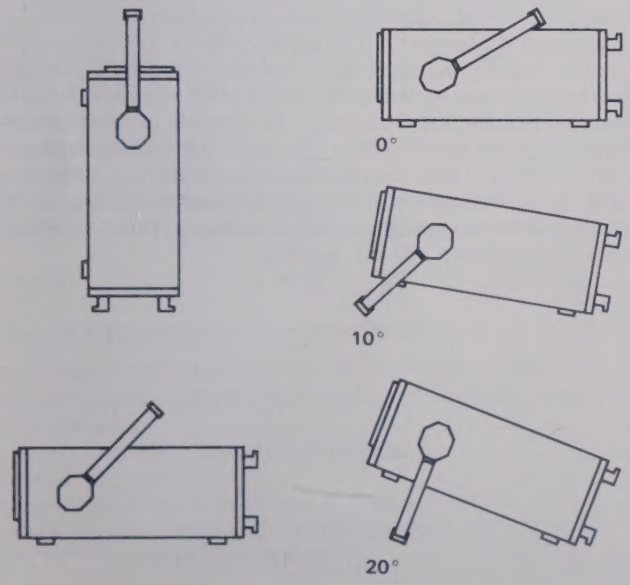
Installation

Inspect the instrument for possible damage in shipment, particularly for physical damage of the case and for loose parts within the instrument. If damage in shipment is noted, notify your supplier. In this case, the instrument must not be used!

Check the line voltage setting (rear instrument panel). If the instrument is set to a wrong line voltage, the power plug must not be connected (see "Getting Started", page 6, for line voltage setting).

Handle

To provide for optimum viewing, the handle can be fixed in three positions (see illustrations). Adjust the handle as follows: Place the instrument in its upright position. The handle will lock in its vertical position. Pull the handle about 5 mm out and tilt it to the desired position (towards the bottom of the instrument). Lock the handle in the required position by slightly pushing it towards the hinges. Set up the instrument at the work site.



Handle in carrying positions

Safety

This instrument is designed and tested according to **VDE 0411, Part 1 and 1a Safety requirements for electronic measuring apparatus**, and has left the factory in perfectly safe condition. To preserve this state and to insure operation without danger, the user must observe the advice and warning notes in these Operating, Test and Service Instructions. **Case, chassis and all measuring terminals are connected to the protective conductor of the power line.** The instrument complies with the specifications of **protection class I.** The touchable metal parts are tested against the line poles with 1500 V, 50 Hz. Due to interconnection with other line-powered instruments, it may be that linefrequency hum voltages occur in the measurement circuit. This can easily be avoided by connecting a protective isolating transformer, protection class II, in front of the M 6003. For safety reasons, the instrument must only be operated on approved safety outlets when an isolating transformer is not used. The protective conductor connection must not be interrupted.

As with most electron tubes, the cathode-ray tube, too, develops γ rays. With the M 6003, the **ionic dose rate falls far below 36 pA/kg.**

If a protective isolating transformer is used for the display of signals with high zero potential, it should be noted that this voltage is also connected to the case and other accessible metal parts of the oscilloscope. Voltages up to 42 V are not dangerous. Higher voltages, however, involve a shock hazard. In this case, special safety measures must be taken and supervised by qualified personnel.

If there is an indication to believe that safe operation is no longer possible, the instrument must be disconnected and secured against accidental operation. This is the case

- — if the instrument has visible damage,
- — if the instrument has loose parts,
- — if the instrument does not function,
- — after long storage under unfavourable conditions (e. g. outdoors or in moist rooms),
- — after excessive transportation stress (e. g. in poor packaging not complying with the requirements of Post Office, Railroad Authorities and Shipping Companies).

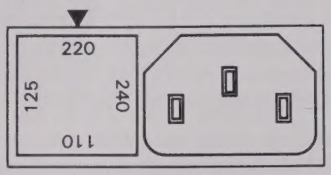
Operating Conditions

The permissible ambient temperature range during operation is from + 10 °C . . . + 40 °C. The permissible ambient temperature range for storage or transportation extends from − 40 °C to + 70 °C. If condensed water has formed during transport or storage, about 2 hours should be allowed for acclimatization before the instrument is put into operation. The oscilloscope is meant for use in clean, dry rooms. It must not be operated in excessivly dusty or moist, explosive and chemically corrosive environments. The oscilloscope can be operated in any position. Sufficient air circulation (convection cooling) must be assured. For continuous operation, the instrument should, therefore, be used preferably in the horizontal or inclined position (tilt stand). The ventilation openings must not be covered!

Getting Started

Caution: Verify that the power connection (protective conductor connection) is made before connecting the measurement circuits.

When delivered, the instrument is set to a line voltage of 220 V. The change to a different voltage is made on the fuse holder (combined with a three-pole appliance plug) at the rear of the case. The fuse holder with its square top plate can be pulled out by means of a tool (e.g. a small screwdriver) after disconnection of the power cord connector from the power outlet, and then plugged in again after turning this plate through 90° for each of the 4 selectable line voltages. The embossed triangle above the fuse holder on the rear instrument panel must then point to the selected line voltage. The selected line voltage is, thus, always readable on the upper edge of the fuse holder.



G-type fuse link: Size **5 x 20 mm**; 250 V AC, C;
IEC 127, Sheet III; DIN 41662 (eventually DIN 41571, Sheet 3).
Cut-out: **delayed action (T)**.

Line voltage	Fuse rating
110 V AC ± 10 %:	T 0.63 A
125 V AC ± 10 %:	T 0.63 A
220 V AC ± 10 %:	T 0.315 A
240 V AC ± 10 %:	T 0.315 A

The power fuse has to match the line voltage and must be changed if necessary. It must be verified that only fuses of the specified type and rated current are used as replacement fuses. The use of patched fuses or shorting of the fuse holder are not permitted.

Cleaning

The exterior of the oscilloscope should regularly be cleaned with a dust brush. Heavy soiling on case and handle, on plastics and aluminium parts can be removed with a damp cloth (water + 1 % detergent). Greasy soiling can be removed with fuel alcohol or benzine (petroleum ether). The screen can be cleaned in the same way and then wiped with a dry, clean, lint-free cloth. Under no circumstances may the cleaning liquid penetrate into the instrument. The use of other cleansing agents can attack the plastic or painted surfaces.

Type of Signal Voltage

Practically all types of periodically recurring signals whose frequency spectrum is below 60 MHz can be displayed on the M 6003. The display of simple electrical processes such as sinusoidal AF and RF signals or line-frequency ripple voltages poses no problem. When square- or pulse-waveforms are displayed, it must be considered that the **harmonic contents** of these signals must also be transmitted. In these cases, the repetition frequency of the signal must be much smaller than the upper limit frequency of the vertical amplifier. An accurate evaluation of such signals with the M 6003 is, therefore, only possible up to a repetition frequency of approximately 6 MHz. Operating problems may sometimes occur when composite signals are to be displayed, especially when they do not contain any level components and a repetition frequency which is suitable for triggering. This occurs, for example, with burst signals. To obtain a stably triggered display in these cases, it may be necessary to use the timebase vernier control and/or the **HOLD-OFF** time control. **Television video signals** are relatively easy to trigger. However, when investigating signals at frame rate, the **TRIG.** selector switch must be set to the **LF** position. In this mode, the more rapid line pulses are attenuated by a low-pass filter so that, with appropriate level adjustment, triggering can easily be carried out on the leading or trailing edge of the frame synchronizing pulse.

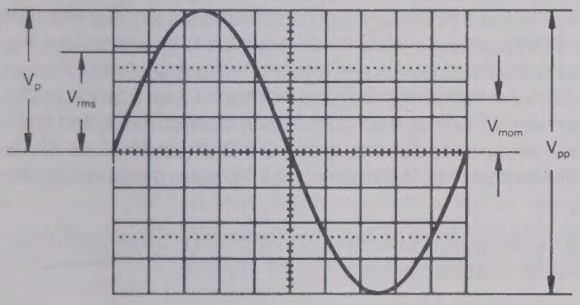
For optional operation as AC or DC voltage amplifier, the vertical amplifier input has a **DC/AC** switch (DC = direct current; AC = alternating current). With DC coupling, the DC position should only be used with an attenuator probe or at very low frequencies, or if the determination of the **DC** voltage content of the signal voltage is absolutely necessary.

When investigating very low-frequency pulses, disturbing rampoffs may occur with **AC** coupling of the vertical amplifier. In this case, **DC** coupling is to be preferred if the signal voltage is not superimposed on a too high DC voltage level. Otherwise, a capacitor of adequate capacitance must be connected in front of the measuring amplifier which is switched to **DC** coupling. This capacitor must have a sufficiently high breakdown voltage. **DC** coupling is also recommended for the display of logic and pulse signals, particularly so if the pulse duty factor changes constantly during operation. Otherwise, the display will move up and down with each change. Pure DC voltages can only measured with **DC** coupling.

Magnitude of the Signal Voltage

In general electrical engineering, alternating voltage data normally refers to the root-mean-square value. However, for signal magnitudes and voltage designations in oscilloscope measurements, the V_{pp} (Volt-peak-peak) value is used. The latter corresponds to the real potential ratios between the most positive and most negative points of a voltage.

If a sinusoidal waveform, displayed on the oscilloscope screen, is to be converted into a root-mean-square value, the resulting peak-to-peak value must be divided by $2 \times \sqrt{2} = 2.83$. Conversely, it should be observed that sinusoidal voltages indicated in V_{rms} have 2.83 times the potential difference in V_{pp}. The relationship between the different voltage magnitudes can be seen from the following figure.



Voltage values of a sine wave
V_{rms} = root-mean-square value; V_p = simple peak value;
V_{pp} = peak-to-peak value; V_{mom} = momentary value

The minimum signal voltage required at the Y-input for a display height of 1 DIV is approximately 1 mV_{pp}, when the **vernier knob** on the input attenuator switch set to **5 mV/DIV** is turned to the right stop and pulled out. However, even smaller signals can also be displayed. The deflection coefficients on the input attenuator are indicated in mV_{pp}/DIV or V_{pp}/DIV. **The magnitude of the applied voltage is found by multiplying the selected deflection coefficient by the read vertical display height in DIV.** If a 10:1 attenuator probe is used, a further multiplication by 10 is required. **For amplitude measurements the vernier control on the input attenuator switch must be set to its calibrated position C** (arrow pointing horizontally to the right). With direct connection to the Y-input, signals up to 400 V_{pp} can be displayed. When pulling the **pull X5** button, the sensitivity of the Y-amplifier is increased by the factor of 5.

With the designations
H = display height in DIV,
U = voltage in V_{pp} at the Y-input,
A = deflection coefficient in V/DIV on the attenuator switch,
the third quantity can be calculated from the two given values:

$$U = A \cdot H \qquad H = \frac{U}{A} \qquad A = \frac{U}{H}$$

With the pull X5 button pulled, A must be divided by 5.

However, these three values are not freely selectable. With the M 6003, they must be within the following limits (trigger threshold, accuracy of reading):
H between 0.5 and 8 DIV, if possible 3.2 and 8 DIV,
U between 1 mV_{pp} and 160 V_{pp},
A between 5 mV/DIV and 20 V/DIV in 1-2-5 sequence,
A between 1 mV/DIV and 4 V/DIV in 1-2-5 sequence,
(with Y vernier control X5 knob pulled).

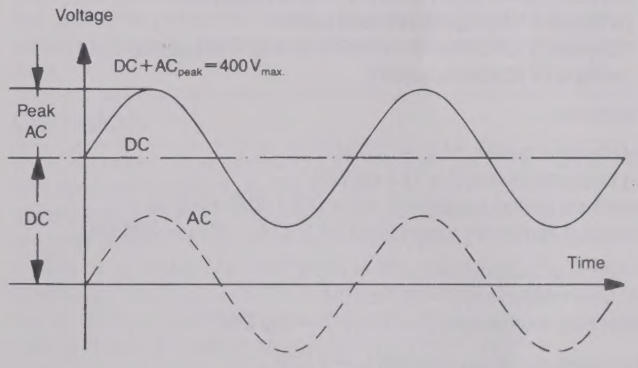
Examples:

Set deflection coefficient A = 50 mV/DIV ≙ 0.05 V/DIV,
observed display height H = 4.6 DIV,
searched voltage U = $0.05 \cdot 4.6 = 0.23\ V_{pp}$

Input voltage U = 5 V_{pp},
set deflection coefficient A = 1 V/DIV,
searched display height H = 5:1 = 5 DIV

Signal voltage $U = 220\ V_{rms} \cdot 2 \cdot \sqrt{2} = 622\ V_{pp}$
(voltage > 160 V_{pp}, with 10:1 probe U = 62.2 V_{pp}),
desired display height H = min. 3.2 DIV, max. 8 DIV,
maximum deflection coefficient A = 62.2:3.2 = 19.4 V/DIV,
minimum deflection coefficient A = 62.2:8 = 7.8 V/DIV,
deflection coefficient to be set A = 10 V/DIV

If the measuring signal is superimposed on a DC voltage, the total value (DC voltage + simple peak value of the AC voltage) of the signal at the Y-input must not exceed ± 400 V (see illustration). The same limit value also applies to normal 10:1 attenuator probes the attenuation of which allows for signal voltages of up to approximately 1000 V_{pp} to be evaluated. Special 100:1 attenuator probes permit the measurement of voltages up to approximately 3000 V_{pp}. However, this value decreases at higher frequencies. When using a normal 10:1 attenuator probe to measure such high voltages there is a risk that the compensation trimmer bridging the attenuator series resistor will break down, causing damage to the Y-input of the oscilloscope. If, however, merely the residual ripple of a high voltage is to be displayed on the oscilloscope, for instance, a 10:1 attenuator probe is sufficient. In this case, an appropriate, high voltage resistant capacitor (approximately 22—68 nF) must be connected in series with the probe.



Total value of the input voltage
The dashed curve shows an AC voltage fluctuating around 0 Volt. If a direct voltage (DC) is superimposed on this voltage, the total voltage value (DC + peak AC) is obtained when the positive peak is added to the DC voltage.

It is explicitly pointed to the fact that the oscilloscope input coupling must absolutely be set to **DC**, if attenuator probes are used for voltages higher than 400 V (see "Connection of Signal Voltage", page 9).

With the input coupling switched to **GND** and with the **Y-POS.** control, a horizontal graticule line can be adjusted prior to the measurement to serve as **reference line for ground potential.** It can be placed below, on, or above the horizontal center line, depending upon whether positive and/or negative deviations from the ground potential are to be measured. Some switchable 10:1/1:1 attenuator probes have a built-in reference switch position for the same application.

Time Values of the Signal Voltage

As a rule, all signals to be displayed are periodically recurring processes, also called periods. The number of periods per second is the repetition frequency. One or more signal periods, or even part of a period, can be displayed as a function of the timebase setting of the TIMEBASE switch. The time coefficients on the TIMEBASE switch are indicated in s/DIV, ms/DIV and µs/DIV. Accordingly, the dial is subdivided into three sectors. The duration of a signal period, or a portion of it, is found by multiplying the relevant portion of time (horizontal distance in DIV) by the time coefficient selected on the TIMEBASE switch. The time vernier control knob marked with an arrow must be in its calibrated position C (arrow horizontally pointing to the right).

With the designations
L = displayed wavelength in DIV,
T = time in s for one period,
F = repetition frequency of the signal in Hz,
Z = time coefficient in s/DIV on the timebase switch
and the relation $F = 1/T$, the following equations can be established:

$$T = L \cdot Z \qquad L = \frac{T}{Z} \qquad Z = \frac{T}{L}$$

$$F = \frac{1}{L \cdot Z} \qquad L = \frac{1}{F \cdot Z} \qquad Z = \frac{1}{L \cdot F}$$

With the pull X 10 button pulled, Z must be divided by 10.
However, these four values are not freely selectable. With the M 6003, they should be within the following limits:
L between 0.2 and 10 DIV, if possible 4 to 10 DIV
T between 5 ns and 10 s,
F between 0.1 Hz and 60 MHz,
Z between 50 ns and 1 s/DIV in 1-2-5 sequence (with pull X 10 button depressed), and
Z between 5 ns/DIV and 0.1 s/DIV in 1-2-5 sequence (with pull X 10 button pulled).

Examples:

Displayed wavelength L = 7 DIV,
set time coefficient Z = 0.5 µs/DIV,
searched period duration $T = 7 \cdot 0.5 \cdot 10^{-6} = 3.5$ µs,
searched repetition frequency $F = 1 : (3.5 \cdot 10^{-6}) = 286$ kHz.

Duration of a signal period T = 0.5 s,
set time coefficient Z = 0.2 s/DIV,
searched wavelength L = 0.5 : 0.2 = 2.5 DIV.

Displayed ripple wavelength L = 1 DIV,
set time coefficient Z = 10 ms/DIV,
searched hum frequency $F = 1 : (1 \cdot 10 \cdot 10^{-3}) = 100$ Hz.

TV line frequency F = 15 625 Hz,
set time coefficient Z = 10 µs/DIV,
searched wavelength $L = 1 : (15\,625 \cdot 10^{-5}) = 6.4$ DIV.

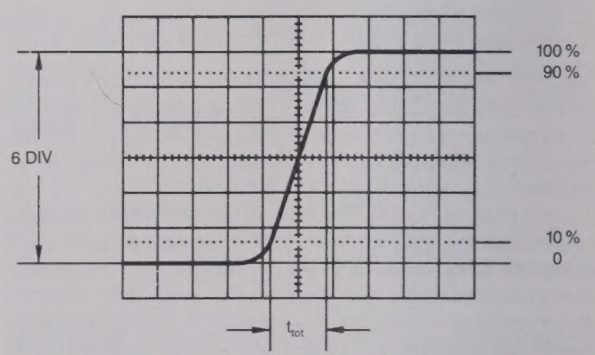
Sine wave length L = min. 4 DIV, max. 10 DIV,
frequency F = 1 kHz,
max. time coefficient $Z = 1 : (4 \cdot 10^{3}) = 0.2$ ms/DIV,
min. time coefficient $Z = 1 : (10 \cdot 10^{3}) = 0.1$ ms/DIV,
time coefficient to be set Z = 0.2 ms/DIV,
displayed length $L = 1 : (10^{3} \cdot 0.2 \cdot 10^{-3}) = 5$ DIV.

HF wavelength L = 0.8 DIV,
set time coefficient Z = 0.5 µs/DIV,
magnification button X 10 pulled: Z = 0.05 µs/DIV,
searched repetition frequency $F = 1 : (0.8 \cdot 0.05 \cdot 10^{-6}) = 25$ MHz,
searched period duration $T = 1 : (25 \cdot 10^{6}) = 40$ ns.

If the portion of time to be measured is relatively short as compared over the complete signal period, an expanded time scale should be used (pull X 10). In this case, the determined time values must be divided by 10. Very small time intervals at any point of the signal can be measured more exactly with the aid of the sweep delay. This allows for — strongly expanded — display of times of less than 1 % of the full signal period. The smallest measurable time interval depends essentially upon the available brightness of the CRT. The limit is an expansion of approximately 1000 times. In certain cases, an increase in expansion can be obtained by means of a viewing hood. For this purpose, it is always required that the time coefficient set on the TIMEBASE switch for the basic period is equal to or greater than 5 µs/DIV (magnification X 10 turned on) as otherwise, the fastest sweep speed determines the greatest possible expansion.

Decisive for the pulse trend of a signal voltage are the rise times and the voltage steps contained therein. To make sure that transients, eventual ramp-offs and bandwidth limits do not unduly influence the measuring accuracy, the rise times are generally measured between 10 % and 90 % of the vertical pulse height. For signal amplitudes, 6 DIV high and symmetrically adjusted to the center line, the internal graticule of the screen has two horizontal, dotted lines in ± 2.4 DIV from the center line. The horizontal time spacing in DIV between the two points at which the trace crosses the dotted graticule lines at the top and bottom with ± 2.4 DIV from the center line is then the rise time to be determined. Fall times are measured analogously.

The following figure shows the optimum position of the vertical display and the measurement range for the rise time.



With a time coefficient of 0.05 µs/DIV set on the TIMEBASE switch and the magnification X 10 button pulled, the measured total rise time in the example above would be

$$t_{tot} = 1.6\,\text{DIV} \cdot 0.05\,\mu\text{s/DIV} : 10 = 8\,\text{ns}$$

With very short times, the rise time of the vertical amplifier of the oscilloscope and the eventually used attenuator probe must be deducted from the measured time value. For the rise time of the signal it then applies

$$t_r = \sqrt{t_{tot}^2 - t_{osc}^2 - t_t^2}$$

Where t_{tot} is the total measured rise time, t_{osc} that of the oscilloscope (for the M 6003 approximately 5.8 ns) and $t_t = 2$ ns, for example. If t_{tot} is greater than 42 ns, then the rise time of the vertical amplifier is negligible (error < 1 %).

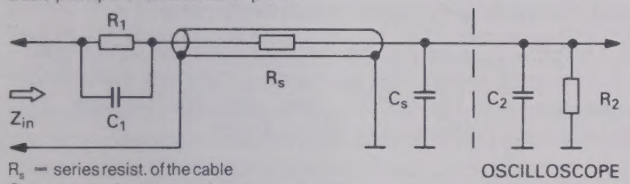
The example in the figure above then results in a signal rise time of

$$t = \sqrt{8^2 - 5.8^2 - 2^2} = 5.1\ \text{ns}$$

Connection of Signal Voltage

The signal to be displayed can be fed to the Y-input of the oscilloscope by means of a shielded test cable either directly or via a 10:1 attenuator probe. The use of the test cables on high-impedance devices under test is only recommended for relatively low frequencies (up to approximately 50 kHz). For higher frequencies, the measuring voltage source must be of low impedance that is, matched to the characteristic cable impedance (usually 50 Ω). Especially when transmitting square-wave or pulse signals the cable must be connected directly to the Y-input of the oscilloscope with a resistor equivalent to the characteristic impedance of the cable. Mainly when transmitting square-wave signals with short rise time, disturbing transient phenomena can become visible on both edges and tops if the correct termination is not used. It must be noted that this termination resistor can only be loaded with a maximum of 2 Watts. This power is reached with 10 V_{rms} or — in the case of a sinusoidal signal — with 28.3 V_{pp}. If a 10:1 attenuator probe is used, no termination is required. In this case, the connection cable is matched directly to the high impedance input of the oscilloscope. With attenuator probes (see illustration) even high impedance voltage sources are only slightly loaded (approximately 10 MΩ ll 16 pF). That is why the attenuator probe should always be used when the voltage loss caused by the attenuator probe can be compensated by a higher sensitivity setting. Furthermore, the series impedance of the probe provides a certain amount of protection for the input of the vertical amplifier. Due to the separate manufacture, all attenuator probes are prebalanced only; that is why exact balancing must be performed on the oscilloscope (see "Probe Adjustment", page 10).

Basic principle of an attenuator probe



R_s — series resist. of the cable
C_s — stray and cable capacitance
C_2 — input capacitance of the oscilloscope
R_2 — input impedance of the oscilloscope
R_1 — series resist. of the attenuator probe
C_1 — compensation capacitor $C_2 \| C_s$

In conjunction with the oscilloscope input, the attenuator probe provides a high bandwidth attenuator.

In compensated condition, the input impedance is calculated by the following relation:

$$Z_{in} \approx \frac{R_1 + R_2}{\omega C (R_1 + R_2) + 1}$$ (applies to f > 20 kHz), where

Z_{in} — input impedance
ω — cyclic frequency $= 2\pi f$, and

$$C = \frac{C_1 \cdot (C_2 + C_s)}{C_1 + C_2 + C_s}$$

The attenuation ratio is expressed as follows:

$$A = \frac{R_2}{R_1 + R_2}; \quad A = \text{attenuation ratio}$$

with $R_1 = 9$ MΩ and $R_2 = 1$ MΩ it follows for

$$A = \frac{1\,M\Omega}{9\,M\Omega + 1\,M\Omega} = \frac{1}{10}$$

If a 10:1 or 100:1 attenuator probe is used, the DC input coupling must always be used with voltages of more than 400 V. With AC coupling of low-frequency signals, attenuation is frequency-dependent, the pulses can show ramp-offs, DC voltages are suppressed — but load the respective input coupling capacitor of the oscilloscope the maximum electric strength of which is approximately 400 V (DC + peak AC). That is why the DC input coupling is particularly important with a 100:1 attenuator probe the permissible electric strength of which is max. 1200 V (DC + peak AC) in most cases. For the suppression of disturbing DC voltages, a capacitor of adequate capacitance and electric strength may be connected in front of the input of the attenuator probe (e.g. ripple measurements).

With the 100:1 attenuator probe, the permissible input AC voltage is limited as a function of the frequency:

below 20 kHz (TV line frequency!) to

$$\text{max. } 1200\,V_p \triangleq 2400\,V_{pp} \triangleq 850\,V_{rms};$$

above 20 kHz (with f in MHz) to

$$\frac{212}{\sqrt{f}}\,V_p \triangleq \frac{424}{\sqrt{f}}\,V_{pp} \triangleq \frac{150}{\sqrt{f}}\,V_{rms}.$$

The selection of the ground point on the device under test is an important feature for the display of low signal voltages. It should be located as close to the measuring point as possible. If this is not the case, the measured result may seriously be falsified by eventually available spurious currents through ground lines or parts of the chassis. The ground leads of attenuator probes are particularly critical. They should be as short and thick as possible. For the connection of the probe to a BNC socket, a BNC adapter should be used which is often included with the supply. Grounding and matching problems are then eliminated.

Hum or interference voltages appearing in the measurement circuit (especially with a small deflection coefficient) are possibly caused by multiple grounding, because through it equalizing currents can flow in the shielding of the measuring cables (voltage drop between the protective conductor connections caused by other line-powered devices, e.g. signal generators with anti-interference capacitors).

Operation

As is the case with all oscilloscopes, the front panel is subdivided into sections according to the various functions. The controls for brightness (**INTENS.**), sharpness (**FOCUS**) and trace rotation (**TR**) are arranged on the left directly below the screen. Following are the switch for graticule illumination (**ILLUM.** — illumination), Y overscanning indication (**OVERSCAN** — overscanning indication), calibrator output (**CALIBRATOR 0.2 V/2 V**) with frequency selector switch (**1 kHz** or **1 MHz**) and component tester controls.

The X-Section, located at the upper right next to the screen, contains the power pushbutton (**POWER**) provided with symbols for the **ON** and **OFF** positions. This section also contains the controls for the timebase (**TIMEBASE**), for triggering (**TRIG.** — triggering) for the horizontal trace position (**X-POS.** — X position), and for the sweep delay (**DELAY**). They are explained in detail below.

The Y-Section, located at the lower left next to the screen, contains the controls for the vertical amplifier inputs for CH I and II (**CH. I CH. II** — channel I, II) with their input couplings switches, attenuator switches with vernier controls for the vertical trace position (**POS. I II** — Y position). The four pushbuttons in the Y-Section are for selection of the operating modes of the vertical amplifiers. They, too, are described in detail below.

All details are designed in such a way that even incorrect operation will not cause serious damage. The pushbuttons mainly control minor functions only. Prior to operating the instrument, verify that none of the pushbuttons is depressed. Their use depends upon the application required.

The M 6003 accepts all signals from DC voltage to a frequency of at least 60 MHz (−3 dB).

For sinusoidal signals, the upper limit is even 80 MHz. However, in this frequency range the vertical display height is limited to approximately 4 — 5 DIV. The time resolution poses no problem. For example, at 100 MHz and the fastest adjustable time coefficient (5 ns/DIV), one cycle will be displayed every 2 DIV. The tolerance of the indicated values is only ± 3 % in both deflection directions. All quantities to be measured can, therefore, be determined relatively accurately. It should be taken into account that in the vertical direction approximately from 25 MHz upwards the measuring error will steadily increase with increasing frequency. This is due to the loss of gain of the measuring amplifier. At 40 MHz this reduction is about 10 %. At this frequency, approximately 11 % must be added to the measured voltage value. As the bandwidths of the vertical amplifiers differ (normally between 65 and 70 MHz), the measured values in the upper limit ranges cannot be defined exactly. In addition thereto — as already mentioned — for frequencies above 60 MHz, the dynamic range of the Y final stage steadily decreases with increasing frequency. The vertical amplifier is designed in such a way that the transmission performance is not affected by its own overshoot.

Getting Started

Prior to first time operation compare the voltage set on the voltage selector of the M 6003 with that of the power line! (See page 6 for voltage selection).

It is recommended not to depress any pushbuttons when starting and to set the 4 operating controls with arrows to their calibrated position C. The marker lines provided on five knob caps should nearly vertically point upwards (mid-range position). Note particularly that the push-pull switch connected with the LEVEL control for the selection of the triggering mode is set to the PEAK position that is, not pulled, and that the DELAY sliding switch NORM.-SEARCH-DELAY is set to the uppermost position NORM.

Put the instrument into operation by depressing the red power pushbutton **POWER**. A pilot light will illuminate to indicate the operating state. If, after a warm-up period of 10 seconds a trace will not be visible, it may be that the **INTENS.** control is not properly adjusted, or that the timebase generator is not triggered. It may also be the case that the **POS.** controls need adjustment. Again check that all knobs and pushbuttons are set to the correct position as specified. Particular attention should be paid to the **LEVEL** control. Without a measuring voltage applied, the trace will only be visible when this pushbutton control is depressed and set to the **PEAK** position. If only a single spot appears (Caution, danger of baking!), the **X-Y** pushbutton is probably depressed. This pushbutton must then be released. When the trace is visible, adjust to a medium brightness on the **INTENS.** control, and to a maximum sharpness on the **FOCUS** control. The input coupling sliding switch **DC-AC-GND (CH. I)** should be set to the **GND** position (ground). The input of the vertical amplifier is then shorted. Thus, it is assured that focusing cannot be influenced by external disturbances. Signal voltages eventually available at the Y-input are not shorted with the switch set to **GND**.

To preserve the life of the cathode-ray tube, the minimum intensity setting necessary for the measurement and the ambient light conditions should be used. Particular care is required when a single spot is displayed. An excessive intensity setting may cause damage to the fluorescent layer of the CRT. Switching the oscilloscope off and on at short intervals stresses the cathode of the CRT.

In spite of Mumetal shielding of the CRT, effects of the earth's magnetic field on the horizontal trace position cannot completely be avoided. This depends upon the orientation of the oscilloscope at the work site. A centered trace may not align exactly with the horizontal center line of the graticule. A few degrees of misalignment can be corrected with a small screwdriver by means of a potentiometer accessible through an opening marked TR.

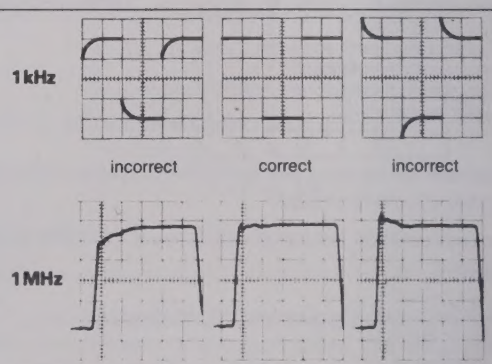
DC Balance Adjustment

After long periods of use, the thermal properties of the dual FETs in the inputs of the two vertical amplifiers may slightly change. This can often also alter the DC balance of the vertical amplifier. This can be found when the trace changes considerably when the input attenuator (small knob with arrow on cap) on **CH. I** and/or **CH. II is pulled**. When the instrument has reached its normal operating temperature, or after it has been in operation for at least 20 minutes, changes of less than 1 mm need no correction. Larger deviations can be corrected with a small screwdriver having a blade width of approximately 3 mm. The correction openings are located on the bottom of the case (approximately 10 DIV from the front edge of the case, approximately aligned with the attenuator switches for Channel I and II; length approximately 20 mm). The balance adjustment device for the blade is funnel-shaped and has a capstan slot so that the screwdriver is easy to insert. While making the correction (deflection coefficient **5 mV/DIV**; input coupling to **GND**), the vernier adjustment knob is pulled and pushed. If the vertical trace position does no longer change, the DC balance is correctly adjusted.

Probe Adjustment

To obtain a full-size display of the signals, the 10:1 attenuator probe used must exactly be matched to the input impedance of the vertical amplifier. For this purpose, the M 6003 has a built-in square-wave generator with a repetition frequency of approximately 1 kHz and 1 MHz (selectable) and an output voltage of 0.2 V_{pp} and 2 V_{pp} ± 1 %. For compensation, simply plug the probe with its sprung hook detached into the proper socket, and compensate its compensation trimmer as shown in the figure located in the center.

The 1 kHz/0.2 V_{pp} output of the calibrator serves to compensate 10:1 attenuator probes. HF attenuator probes are additionally compensated with 1 MHz/0.2 V_{pp} (see probe specifications), for 100:1 attenuator probes the 1 kHz/2 V_{pp} is used.



With the 1 kHz/0.2 V output combination, the **TIMEBASE** switch should be in the **0.2 ms/DIV** position, and the Y input coupling switched to **DC**. If the input attenuator is in the **5 mV/DIV** position (vernier control set to **C**), then the displayed signal will have a height of **4 DIV**. As an attenuator probe is constantly subjected to considerable mechanical and electrical stress, the compensation should frequently be checked.

Your attention is drawn to the fact that the frequencies of the built-in square-wave generators cannot be used for time calibration. Furthermore, the pulse duty factor deviates from the 1:1 value. Finally, it is pointed out that the rise and fall times of the 1 kHz square-wave generator are so short that the edgees are hardly visible even with maximum intensity. This is not a flaw but rather a provision for simple and exact probe compensation (or a check of the deflection coefficient) as horizontal pulse tops, calibrated pulse amplitude and zero potential on the negative pulse top.

Operating Modes of the Vertical Amplifier

The required operating modes of the measuring amplifiers are selected by means of the four pushbuttons in the Y-Section. For **Single** operation, all pushbuttons are in their released position. In this case, only **Channel I** is ready for operation. For **Single** operation with **Channel II**, depress the **CH. II** pushbutton. Select the proper triggering mode in the TIMEBASE-Section. When the **DUAL** pushbutton is depressed, both channels will work. With the pushbutton in this position, two processes are displayed consecutively (alternate mode). This mode is not suitable for the display of very slow processes. The display will then flicker considerably, or it appears to jump. If the **ADD./CHOP** pushbutton is additionally depressed, both channels will constantly be switched with a high frequency during a sweep period (chop mode). Flicker-free display is then also possible for slow processes. For the display with higher repetition frequency, the type of channel selection is less important. If only the **ADD./CHOP** pushbutton is depressed, the signals of both channels are added (**I+II** = summation display). If, in addition thereto, one channel is inverted (**CH I INV.** pushbutton depressed), then also the difference can be displayed. For both of these operating modes, the vertical position of the trace depends upon the **Y-POS.** controls of both channels.

For X-Y operation, depress the **X-Y** pushbutton in the TIMEBASE-Section. The X signal is then fed across the input of **Channel II. With X-Y operation, the input attenuator and vernier controls of Channel II are used for the amplitude setting in the X-direction.** However, the **X-POS.** pushbutton must be used for horizontal trace positioning. The position control of Channel II is disconnected with X-Y operation. Maximum sensitivity and input impedance are now identical in both directions of deflection. The **pull X 10** push-pull switch for the expansion of the time line, connected with the **X-POS.** control knob, should not be pulled in this case. The limit frequency in the X-direction is approximately 5 MHz (– 3 dB). But it should be noted that a considerable increase in phase difference occurs already from 100 kHz upwards which increases constantly with higher frequencies.

Signal voltages between two high switching points are often measured in **difference mode** of both channels. In this way, also currents between two high switching components can be determined as voltage drop across a known resistance. In general, it applies that for the display of difference signals the two signal voltages must only be picked up with attenuator probes of precisely the same impedance and attenuation. For some difference measurements it is of advantage **not** to connect the grounding cable of the two attenuator probes to the device under test. This can prevent eventually available hum or common mode interferences.

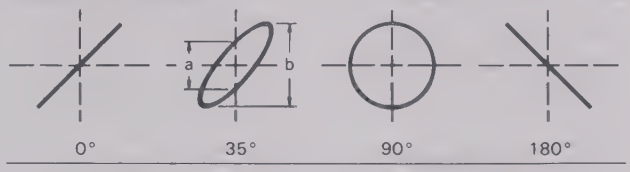
Be careful when connecting unknown signals to the vertical input! When a series-connected attenuator probe is not used, the signal coupling switch should first be set to **AC**, and the input attenuator switch should be set to **20 V/DIV.** If, after applying the signal voltage, the trace suddenly disappears, it may be that the signal amplitude is much too great and completely overdrives the vertical amplifier (see "Y Overscanning Indication"). In this case, turn back the attenuator switch to the left until the vertical signal height is only 3 – 8 DIV. With a signal amplitude greater than 160 V_{pp}, it is absolutely required to connect an attenuator probe in series. If, after connection of the signal, the trace is nearly blanked, the signal period is probably substantially longer than the value set on the **TIMEBASE** switch. It must then be turned to the left and set to a correspondingly greater time coefficient.

X-Y Operation

X-Y operation with Lissajous figure facilitates or enables certain problems to be measured:

- Comparison of two signals of different frequencies or adjustment of one frequency to the frequency of the other signal until synchronization is reached. This still applies also to integral multiples or parts of a signal frequency.
- Phase comparison between signals of like frequency

Phase comparison with Lissajous figure
The following illustrations show two sinusoidal signals of like frequency and amplitude having different phase angles.



The phase angle or the phase shift between the X and Y input voltages (after measuring length **a** and **b** on the screen) can easily be calculated by the following equations and a pocket calculator with angular functions and, by the way, **independent of the deflection amplitudes** on the screen.

$$\sin \varphi = \frac{a}{b}$$

$$\cos \varphi = \sqrt{1 - \left(\frac{a}{b}\right)^2}$$

$$\varphi = \text{arc sin } \frac{a}{b}$$

Note the following:

- Due to the periodicity of the angular function, mathematical evaluation should be limited to angles ≦ 90°. It is exactly here that the advantages of this method are found.
- Do not use too high a measuring frequency. Above 100 kHz, the phase shift of the two oscilloscope amplifiers of the M 6003 can exceed an angle of 3° with X-Y operation.
- It cannot readily be seen on the screen whether the test voltage is leading or lagging as compared over the reference voltage. A CR-element in front of the test voltage input to the oscilloscope is a useful means in this case. The 1 MΩ input resistance can serve as R so that merely an adequate capacitor must be connected in series. If the opening width of the ellipse (to shorted C) increases, the test voltage is leading and vice versa. This only applies to the range of up to 90° phase shift. That is why C should be sufficiently large and only cause a relatively small, just well visible phase shift.

If, with X-Y operation, both input voltages are missing or failing, a very bright spot is displayed on the screen. Too high an intensity setting (INTENS. pushbutton) can cause this spot to bake into the fluorescent screen resulting in either a lasting loss in brightness or, in extreme cases, in complete damage to the fluorescent screen at this point.

Y Overscanning Indication

This indicating facility shows any overscanning of the usable screen area in the vertical direction, if the trace line or signal portions of more than 100 ns duration (needle pulses) are not within the graticule. Indication is via two lightemitting diodes, marked **OVERSCAN**, which are located on top of each other in the operating control field immediately below the screen. If one lamp lights without a measuring signal being applied, then this is an indication that the X-POS.

control is misadjusted. It can be seen from the assignment of the lamps in which direction the trace has left the screen. With dual channel operation, misadjustment of both **Y-POS.** controls can be the case. If both traces lie in the same direction, in this case, too, only one lamp illuminates. If one trace is positioned above and the other below the screen, both will light. Indication of the Y position after crossing the graticule area occurs **in each operating mode,** that is, even when no time line is displayed because of missing time deflection, or when the oscilloscope operates in the X-Y mode.

As already described previously under "Getting Started", automatic peak value triggering **PEAK** (**LEVEL** pushbutton depressed) should be used as often as possible. A baseline is then permanently displayed even without a measuring signal. Sometimes, the trace disappears after applying a measuring signal. The indication then shows where it is located. If both lamps light simultaneously when the signal voltage is applied, then it is indicated that the graticule has been overscanned in both directions. If the signal is superimposed on a relatively high DC voltage, the raster edges can be overscanned with **DC** coupling of the vertical amplifier because the DC voltage causes a vertical position shift of the seemingly correctly adjusted display height. In this case, a smaller display height must be accepted, or **AC** coupling must be selected.

Lighting of the **OVERSCAN** indication does not imply that the display in the setting just selected must always be distorted. The measuring amplifier has a certain overdriving reserve. It should be checked, however, that the swing limit is not exceeded. This is simply done by turning the appropriate attenuator switch one step to the left. If the **OVERSCAN** indication is then extinguished, the previous setting can still be used, e. g. to check the top of square-wave pulses with vertical expansion. However, this does no longer apply with frequency portions above 25 MHz because, in this case, the reserve naturally gets smaller and smaller.

Triggering and Timebase

The display of a signal is only possible when the timebase is triggered. In order to obtain a stable display, triggering must be synchronous with the test signal. This is possible by means of the test signal itself or by an external but also synchronous signal voltage. If the **LEVEL** control knob is in the **PEAK** position, a baseline will be displayed even if a measuring voltage is not applied. In this position, virtually all uncomplicated, periodically repeating signals above a repetition frequency of 30 Hz can stably be displayed. Timebase control is then mainly limited to the time adjustment. The trigger point on the signal can be selected with the **LEVEL** control. Its range is always balanced automatically to the peak-to-peak amplitude of the signal just applied. The advantage of this trigger mode is that the trigger point shift is more independent of the display height just selected and of the shape of the signal. For example, the pulse duty factor of a square voltage can be changed from 1:1 to 100:1. It can happen that in a previous measurement the **LEVEL** control was adjusted nearly to its stop. Triggering may then eventually fail for the following measurement as a result of a change in display height and/or signal shape. Stable display can be regained by a slight adjustment on the **LEVEL** control towards the mid-range position.

This **automatic peak triggering** operates in principle also with external triggering via the **EXT. TRIG.** socket. However, the required (synchronous) signal voltage should be in the range of approximately 50 mV_{pp} to 0.5 V_{pp}. With **normal triggering** (LEVEL knob pulled) and LEVEL adjustment, sweep and/or triggering of the timebase can be at any point of a signal edge. If the display of a signal is to start on a negative-going edge, then the pushbutton marked +/− must be depressed. The triggering range covered by the **LEVEL** control depends to a great extent upon the amplitude of the displayed signal. If it is smaller than 1 DIV, adjustment should be performed with a sensitive touch because the range covered is very small.

For internal triggering and single channel operation, the lower trigger selector switch arranged below the **TIMEBASE** control must be set to position **I** or **II**, depending upon the vertical input selected. In the dual channel mode, the internal trigger signal can be selected from Channel I or II. Set to position **ADD.** (**ADD** pushbutton depressed) and alternate mode, it is also possible to use **at the same time internal** normal triggering on both channels. **The two signal frequencies may then be asynchronous.** Display of one signal only is not possible when the alternate trigger mode is selected. With all other operating modes, only Channel I is always connected through when the **I/II** position is used.

For external triggering, switch the trigger selector switch to **EXT.** and feed the signal (50 mV_{pp} to 0.5 V_{pp}) to the **EXT. TRIG.** socket. With single channel mode, the **external signal** may also be **fed via the input of Channel II** (trigger selector switch set to position **II**). This is particularly recommended when the amplitude of the trigger signal is not between 50 mV_{pp} and 0.5 V_{pp}, or if it is of an unknown value. In this case, it can be matched to the trigger input of the timebase in an optimum way on the range from 5 mV to approximately 150 V_{pp} by means of the **Y-AMPL.** switch of Channel II. It is of advantage to first display the external trigger signal and adjust it to an amplitude of 2—6 DIV. Then, switch back to **CH. I**, but leave the trigger selector switch set to position **II**.

The coupling mode and the frequency range of the trigger signal are internally and externally selectable with the trigger selector switch at the left of the TIMEBASE pushbutton. In the **AC** or **DC** mode, small signals (< 2 DIV) are only triggered up to approximately 20 MHz. For higher frequencies (20—80 MHz) switch to the **HF** position. With **AC** and **DC**, frequencies above 20 MHz are strongly suppressed. The advantage of this is that double triggering, caused by amplifier noise, is nearly avoided on the lower frequency range even with maximum intensity of the measuring amplifier. DC triggering is recommended only when very slow processes triggering is to be made to an appointed level value of the measuring signal, or when pulseshaped signals of strongly changing pulse duty factors during the measurement must be displayed. With internal DC triggering it is recommended to always use **normal triggering** and **LEVEL** adjustment. Otherwise, it could be that in the **PEAK** mode a not exactly adjusted **DC Balance** may change the triggering point, or that triggering will not be achieved with signals having no zero-axis crossing. The balance of the relevant vertical input must then be corrected.

As already described, simple signals can automatically be triggered in the **PEAK** mode. The repetition frequency may also vary in such cases. However, if the pulse duty factor on a square-wave signal changes drastically so that one part of the square deforms to a needle pulse, a change to **normal triggering** with **LEVEL** adjustment may become necessary. With composite signals, the trigger facility depends upon certain periodically recurring level values. **LEVEL** adjustment to these level values requires some care.

For **line triggering** with the trigger selector switch set to **LINE**, a (divided) secondary winding voltage of the power transformer is used as a line frequency trigger signal (50—60 Hz). This trigger mode is independent of amplitude and frequency of the Y-signal, and it is recommended for all line-synchronous signals. This also goes — within certain limits — for integral multiples or portions of the line frequency. The line triggering mode allows for the display of a signal even below the trigger threshold. That is why it is particularly suited for the measurement of small ripple voltages from power supply rectifiers or line frequency leakage fields in a circuit.

If the **video signal of a television set** is to be displayed **at frame frequency**, the trigger selector switch must be set to the **LF** (low frequency) position to attenuate the line pulses. This setting is also used to advantage when triggering other signals having a repetition rate of less than 800 Hz because high frequency interference and noise in the trigger voltage supply are suppressed by the presence of the low-pass filter.

If it is found that a stable trigger point cannot be located on extremely complex signals even after repeated and careful adjustment of the LEVEL control in normal triggering mode, it is possible in many cases to obtain a stable display with the aid of the HOLD-OFF control. With this facility, the hold-off time between two sweep periods can be increased continuously in a 10:1 ratio. Pulses or other signal waveforms appearing during this hold-off period cannot influence the triggering anymore. Particularly with burst signals or aperiodic pulse trains of like amplitude, the start of the triggering phase can then be shifted to the optimum or required moment.

Double display of an extremely noisy signal, or of a signal disturbed by a higher frequency may sometimes occur. It may be the case that only phase shifting can be influenced with the LEVEL control but not the double display. The staple single display required for the evaluation of the signal can easily be obtained by an increase of the HOLD-OFF time. Slowly turn the HOLD-OFF button to the left until only one signal is being displayed. Upon completion of this work, absolutely reset the HOLD-OFF control to the right stop, otherwise the brightness of the display is drastically reduced.

Working Principle of the Variable Hold-off Time Control

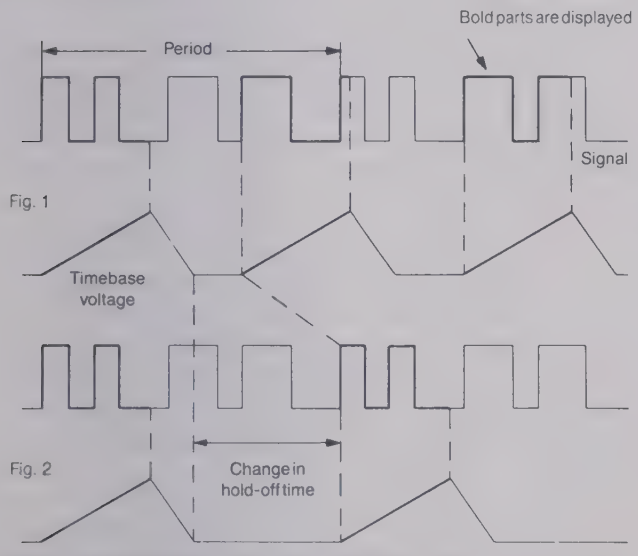


Figure 1 shows the screen display with the HOLD-OFF control set to the right stop (basic setting). As different parts of the waveform are displayed, a stable display is not obtained (double display).
Figure 2: In this example, the hold-off time is selected in such a way that the same parts of the waveform are always displayed. A stable display is obtained.

If the signal to be measured is of complex shape and consists of two or more recurring frequencies (periods), triggering may pose a problem. In this case, the variable hold-off time is a useful means. By varying the off time (up to 10:1) between two sweeps of the timebase, it is normally always possible to obtain a stable display on the screen.

The working prinicple can be found from the above illustrations.

Single Sweep

Single processes, e.g. single interference pulses, or the display of the dying out of a resonant circuit after pulse excitation can be displayed by single sweep. For this, depress the SINGLE pushbutton. Arranged above the RESET pushbutton is a light-emitting diode marked READY which indicates the readiness of the sweep. If it is not illuminated, the RESET pushbutton must also be depressed. In some cases, automatic peak value triggering can be used for the display of individual images. The trace then starts at about the baseline level. Triggering is then very sensitive, but already very small, accidentally occurring interference pulses can trigger a premature sweep. For the triggering at higher or lower level values, or with very low frequencies, normal triggering mode and manual LEVEL adjustment are of much greater advantage. Eventually determine the adequate setting earlier with normal timebase operation using a similar signal voltage. If correctly adjusted, the next following trigger pulse starts the single sweep. After that, the READY light-emitting diode goes out. To repeat this action, again depress the RESET pushbutton. With single sweep, only relatively slow processes can be observed visually. The number of the displayed waveforms increases with an increase in the time coefficient. In most cases, photographic registration is recommended.

All time coefficient settings on the TIMEBASE switch are referred to the right stop position of the vernier control marked VAR. and to a length of the baseline of 10 DIV. When a 10-times expansion of the time-axis (pull X 10 button pulled) is used, a maximum resolution of approximately 5 ns/DIV is obtained when the TIMEBASE switch is set to the 0.05 µs/DIV position. The choice of the optimum time range depends upon the repetition frequency of the measuring voltage applied. The number of waveforms displayed increases with the increasing time coefficient.

Trigger Indicator

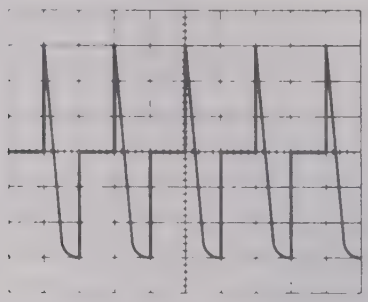
Both with PEAK and with NORMAL triggering, the triggered condition of the timebase is indicated by a light-emitting diode next to the trigger selector switch. This facilitates a sensitive LEVEL adjustment, particularly with signals of low frequency. The pulses which control the trigger indicator are stored for approximately 100 ms only. With signals having an extremely slow repetition rate, the lamp will flash more or less.

Sweep Delay

With the sweep delay, the start of the sweep can be delayed from the trigger point by a selectable time (100 ns to max. 1 s). It is, thus, possible to start the sweep practically at any point of the signal period. The interval following the start of the sweep can be displayed greatly expanded by an increase in the sweep speed. From the 5 µs/DIV on down to slower sweep speeds, an expansion of at least 100 times and including the pull X 10 magnification of even 1000 times is possible. With time coefficients higher than 5 µs/DIV, the maximum expansion increases proportionally. However, the brightness of the display decreases with increasing expansion. If required, the brightness can be increased (turn the INTENS. control further to the right and newly adjust the FOCUS control). In very bright environments, a viewing hood may be necessary to view a strongly expanded display. Some difficulties arise when the test signal has heavy inherent jitter. This can be recognized by the fact that — caused by irregular frequency fluctuations of the generator — double displays of reduced brightness and sharpness.

Operation of the sweep delay is relatively easy. Starting from normal oscilloscope operation (DELAY sliding switch set to NORM.), the signal to be delayed is at first displayed with 1 to 3 basic periods. A larger number unnecessarily decreases the brightness of a strongly expanded display. The display of only a portion of a period limits the choice of the expanded time interval and eventually complicates triggering. On the other hand, the range of 1 to 3 basic periods can always be set unconstrainedly with the TIMEBASE switch. In this case, the X 10 expansion should be switched off (small X-POS. control depressed), the HOLD-OFF control must remain in the X 1 calibration position, and the time vernier control set to C. The LED indicator next to the DELAY sliding switch does not light in this case. For the further process, triggering must be adjusted to a well-triggering edge.

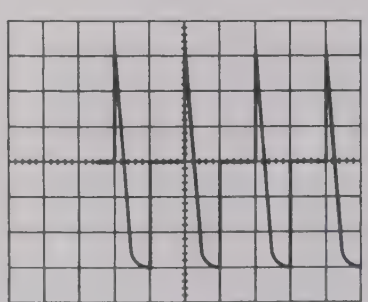
Figure 1



MODE : NORM.
TIMEBASE : 0.5 ms/DIV
LED : off

Then, set the **DELAY** sliding switch to the **SEARCH** position. Thereby, the (left) beginning of the trace will shift more or less to the right. This shift shall not be eliminated by use of the **X-POS.** control. If the **DELAY** time range switch is set to **0.1 µs**, it is possible that the shift is hardly visible — independent of the time coefficient set on the **TIMEBASE** switch. If this is the case, turn the range switch to the right until the trace starts just before the time interval to be expanded. Exact setting to the beginning of the time interval of interest is made with the **VAR. 10:1** DELAY control on the range selector switch. The range of rotation of the **VAR.** control has no stop position. A slight snapping noise is audible at the range limits. When starting DELAY operation, this control should be set to the left start position. If the timebase disappears completely after switching to **SEARCH**, it normally indicates that the **DELAY** range switch is set to too high a delay time. Turn it to the left until the beginning of the trace starts at the left of the time interval to be expanded. In the **SEARCH mode, the light-emitting diode in the DELAY section will flash.**

Figure 2

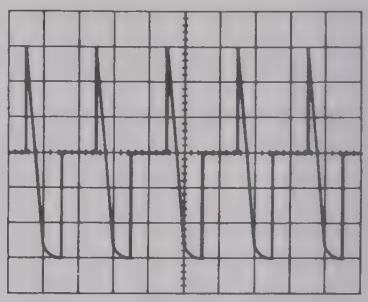


MODE : Search
DELAY time range : 1 ms
TIMEBASE : 0.5 ms/DIV
LED : flash
Delay time = 2.5 DIV · 0.5 ms/DIV = 1.25 ms

It can be seen from Figure 2 that the delay time can also be measured. It is identical with the adjusted shifting of the beginning of the trace. It is determined by multiplication of the horizontal shifting in DIV by the time coefficient set on the **TIMEBASE** switch.

The **DELAY** sliding switch can now be set to **DELAY** (timebase sweep speed delay). The beginning of the trace, starting with the selected time interval, will move to the same position as for the display in **NORM.** mode, that is, to the left. Now, the indicator in the DELAY-Section will constantly light (see Figure 3).

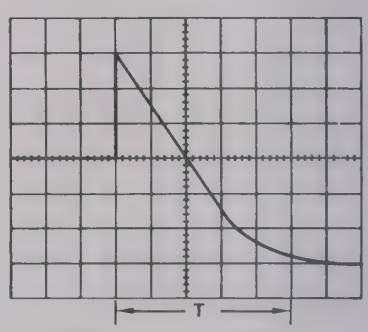
Figure 3



MODE : Delay
DELAY range : 1 ms
TIMEBASE : 0.5 ms/DIV
LED : constantly illuminated

The time interval to be investigated can now be expanded to a great extent by increasing the sweep speed. Any desired shift of the expanded portion is possible — also later — with the **VAR.** DELAY vernier control. As can be seen from the example in Figure 4, a ten-**fold expansion was obtained by changing the setting on the TIME-BASE** switch from 0.5 ms/DIV to 50 µs/DIV. Thanks to the expansion, time measurements on the expanded portion can now be made more accurately. For this purpose, the horizontal length in DIV of any signal portion must be multiplied by the time coefficient being set on the **TIMEBASE** switch. The time vernier control on the **TIME-BASE** switch must be set to its calibrated position **C**.

Figure 4



MODE : Delay
DELAY range : 1 ms
TIMEBASE : 0.05 ms/DIV
LED : constantly illuminated
Expansion : $0.5 \cdot 10^{-3} : 50 \cdot 10^{-6} = 10$
T = 5 DIV · 50 µs/DIV = 250 µs

Naturally, expansion is not limited to the factor of 10 chosen in the example. As already mentioned, much wider expansions are possible when the **TIMEBASE** switch is turned further to the right. It is only limited by the fact that the brightness of the trace reduces with increasing expansion. Application may also become difficult with signal jitter (irregular frequency fluctuations of the generator).

A constant trigger point is essential when operating with the sweep delay. All kinds of signals which have a constant phase shift between the expanded portion to be displayed and the trigger point pose no **problem. This means all electrical signal shapes which contain sig-**nal edges of the same polarity and triggerable level values which are constantly repeated with the repetition frequency. If phase stability does not exist, triggering may fail when switching from **SEARCH** to **DELAY**, or when changing the time coefficient. In this

case, it should be tried to find a trigger point already in normal mode (display of the basic period of the signal) which is constant in phase with the signal portion to be expanded. With complicated composite signals, it is possible that other signal portions are superimposed on the display of the basic period. Normally, they disappear when the sweep is increased. Otherwise, a stable expanded display is obtained by adjusting the **LEVEL** control, the vernier sweep control, or the **HOLD-OFF** control. Using the **pull X 10** expansion, each portion can additionally be expanded by the factor of **10** without any change in timebase or delay time. This can be useful with signals that are difficult to trigger.

Operation of the sweep delay requires certain experience, particularly in the case of composite signals that are difficult to display. However, the display of portions of simple kinds of signals is easy right from the start. It is recommended to always follow the given sequence **NORM.-SEARCH-DELAY** as otherwise, it may be relatively difficult to locate the desired time range. The sweep delay facility can also be used with dual channel operation and in the display of sum and difference.

Delay Indication

The operating modes of the sweep delay are indicated by the LED lamp located at the right of the DELAY sliding switch. When switched to **SEARCH**, the light-emitting diode starts to flash. This is meant to indicate a non-standard condition. The **DELAY** position is indicated by constant lighting of the LED. If this is noted in normal mode **without** sweep delay, it has been overlooked to set the DELAY sliding switch to **NORM.**, errors may be caused, such as complete or partial blanking of the trace. That is why this light-emitting diode must be observed closely.

Component Tester

The M 6003 has a built-in component tester which is ready for use the instant the CT pushbutton is depressed. Two-pole connection of the component to be tested is made via the insulated socket in the framed **Component Tester** Section (at the right, below the screen) and via one of the ground sockets in the Y-Section. With the **Component Tester** pushbutton depressed, both the Y-preamplifier and the timebase generator are inoperative. However, signal voltages applied to the three BNC sockets at the front need not be disconnected. Their leads may remain connected (see "In-circuit Tests"). All oscilloscope settings, with the exception of the **INTENS.**, **FOCUS** and **X-POS.** controls, have no influence on the test operation. Connection of the device under test to the CT sockets requires two simple test leads with 4 mm banana plugs. After the test, normal operation of the oscilloscope can be resumed by releasing the CT pushbutton.

In line with the protection class of the M 6003 and the protection class of other line-powered devices eventually connected across the test leads, it is possible that the socket marked with the ground symbol is connected to the protective conductor of the power supply, that is, grounded. In general, this is of no importance for the testing of individual components.

When making in-circuit tests, the latter must by all means be disconnected. With line circuitry with protective ground, it is required to remove the power plug of the circuit to be tested so that its protective ground connection is also interrupted. A double protective conductor connection would falsify the result of the tester.

Test discharged capacitors only!

The test principle is fascinatingly simple. The power transformer of the M 6003 delivers a sinusoidal voltage of line frequency which feeds the series connection of device under test and built-in resistor. The sinusoidal voltage is used for the horizontal deflection, and the voltage drop across the resistor is used for the vertical deflection.

If the device under test is a real quantity (e. g. resistance), then both deflection voltages are identical in phase. A more or less sloping line is displayed on the screen. If the device under test is shorted, the line will be vertical. In the case of interruption, or without a device under test, a horizontal line will be displayed. The angle of slope of the line is a measure for the resistance value. Ohmic resistances of between 20 Ω and 4.7 kΩ can, thus, be tested.

Capacitors and **inductors** (coils, chokes, transformer windings) **cause a phase difference between current and voltage, that is, also** between the deflection voltages. This results in ellipse-shaped displays. **Position and opening width of the ellipse are characteristic for the impedance value at line frequency.** Capacitors are displayed on the range from **0.1 µF** to **1000 µF**.

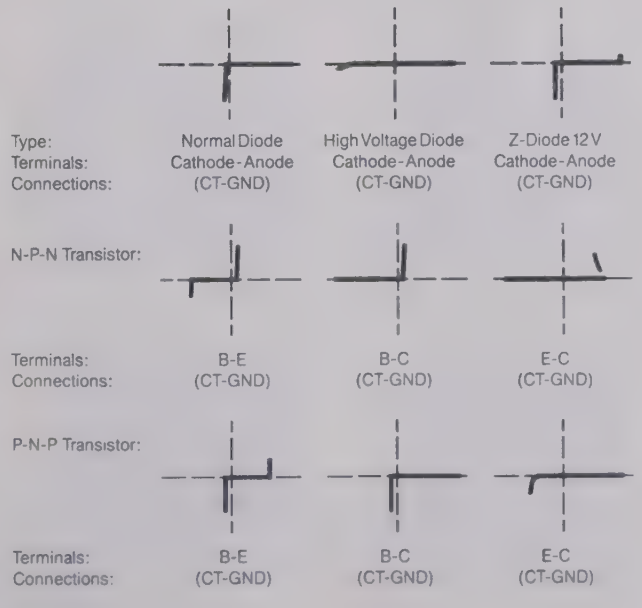
A horizontal ellipse indicates a high impedance (small capacitance or high inductance).

A vertical ellipse indicates a small impedance (large capacitance or small inductance).

A sloping ellipse indicates a relatively large ohmic resistance in series with the reactance.

With semiconductors, the voltage-dependent knees of the characteristics are recognized when changing from the conducting to the non-conducting state. Where possible, both the **forward and the reverse characteristic** are displayed (e. g. zener diode below 12 V). This is always a two-pole test; that is why transistor gain, for instance, cannot be tested, but testing of the single junctions B-C, B-E, C-E is possible. As the voltage applied to the device under test amounts to but a few Volts only, the individual sections of all **semiconductors can be tested without damage.** However, checking the breakdown or reverse voltage of high voltage semiconductors is not possible. Generally, this is not a drawback as heavy deviations occur anyway in case of a faulty circuit which clearly point to the faulty component.

Rather accurate results are obtained by a **comparison with absolutely functioning components** of like type and values. This is especially also true for semiconductors. The connection on the cathode side of a diode or zener diode with illegible printing, distinction between a p-n-p transistor and its complementary n-p-n type, or the proper B-C-E case connection sequence of an unknown transistor type can quickly be determined.



Please note that **polarity inversion of a semiconductor connection** (exchanging the CT socket with the ground socket) effects a **rotation of the test pattern through 180°** around the graticule center of the CRT.

Even more important is the simple Good/Bad determination of interrupted or shorted components, which is most frequently needed in the field of service, as is known from experience.

Pay attention to the usual caution with single MOS-components relating to static charge or frictional electricity. Hum may also be displayed on the screen when the base or gate connection of a single transistor is open, that is, not tested at the moment (hand sensitivity).

In-circuit tests are possible in many cases but they are not so well-defined. Due to parallel connection of real and/or complex quantities — especially if they are of relatively low impedance at line frequency — to the component under test, often results in great differences as compared over single components. When frequently working with circuits of like type (servicing work), **comparison with a functioning circuit** is helpful here, too. This is a particularly quick way as the comparison circuit need not (and must not!) be powered. Using the test cables, check the identical test point pairs successively and compare the displays. Possibly, the device under test itself contains the comparison circuit, e.g. in the case of stereo channels, push-pull operation, symmetrical bridge circuits. In the case of doubt, one end of a component terminal can be desoldered. Exactly this terminal should then be connected to the **CT test socket without a ground symbol** as this reduces the hum interference. The test socket bearing the ground symbol is taken to the oscilloscope ground and is, thus, insensitive to hum interference.

With in-circuit testing, it is required to disconnect the test leads and attenuator probe connections between the BNC sockets of the M 6003 and the circuit. Otherwise, test point sweeps cannot freely be selected (double ground connection).

The test patterns on page 17 show some practical examples for the use of the component tester.

Miscellaneous

The sawtooth voltage of the sweep generator (approximately 5 V_{pp}) is available at a BNC socket, marked **⎓**, at the rear of the instrument. The load resistance should not be smaller than 10 kΩ. For pick-up without a DC voltage potential, a capacitor must be connected in series.

Blanking of the trace is effected by Low TTL level (positive logic) at the BNC socket marked **Z**-modulation which is also arranged at the rear of the instrument. Voltages higher than TTL level (5 V_{pp}) are not permitted for trace modulation. The sine-wave or square-wave generator required for blanking should have a relatively low output impedance (max. 600 Ω). A square-wave generator with negative pulses to ground cannot be used. Also an offset DC voltage must not be applied to the Z-socket. For setting the blanking duty factor, the output voltage of a sine-wave generator must be adjustable. Trace modulation occurs in bright-dark steps. Analog modulation with gradation of tones is not possible. Z-modulation can also be effected directly at the Z-socket by means of a mechanical switch (without a power source):

Contact shorted	≙ dark
Contact open	≙ bright

This facility for instance, simplifies time measurements and chatter tests on switches (relays). For periodical switch operation, the drive unit should usefully also deliver a trigger signal. A stationary display is only obtained with synchronous operation of Z-modulation and timebase.

The M 6003 incorporates a Y-output with BNC socket on the rear of the instrument. The output voltage is approximately 100 mV_{pp}/DIV display height in open-circuit condition. The Y-voltage — same as the trigger signal — is derived from the vertical amplifier and is equally switchable. Channel I or II is selected with the I/II trigger pushbutton in the X-Section. With alternate channel switching (only **DUAL** pushbutton in the Y-Section depressed) and alternate triggering (**ADD.** pushbutton in the X-Section depressed), the Y-output is alternately driven (in time with the sweep period) from Channel I and II. The Y-output is independent of the Y-trace position. It does neither respond to an adjustment of the **Y-POS. I** or **Y-POS. II** controls nor to the invert pushbutton **CH I INV.** The Y-output operates with DC coupling and has approximately zero potential. Its bandwidth is approximately 60 MHz when it is terminated externally with 50 Ω. The output voltage is then approximately 50 mV_{pp} per DIV display height.

For the photographic recording of displays, the M 6003 has a raster illumination. Without this illumination, the raster which is required for the evaluation is not visible. Variation of the brightness in two steps is possible on the sliding switch marked **ILLUM.** In the uppermost position **0**, the raster illumination is switched off. An optimum setting also depends upon the camera and the film exposure index used. Possibly, some test pictures are required for a good representation of the graticule.

Maintenance

Within the context of maintenance, it is recommended to regularly check some important characteristics and criteria of the M 6003. The following Test Instructions indicate only those tests that can be performed without the use of expensive ancillary instruments.

Test Patterns Single Components

Short circuit

Resistor 510 Ω

Power line transformer prim.

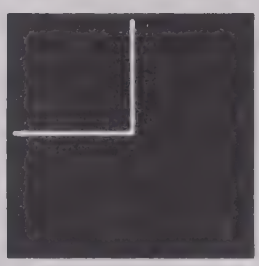
Capacitor 33 µF

Test Patterns Single Transistors

Junction B-C

Junction B-E

Junction E-C



FET

Test Patterns Single Diodes

Z-diode under 8 V

Z-diode above 12 V

Silicon diode

Germanium diode

Rectifier

Thyristor G + A togheter

Test Patterns In-circuit Semiconductors

Diode parallelled by 680 Ω

2 Diodes antiparallel

Diode in series with 51 Ω

B-E parallelled by 680 Ω

B-E with 1 µF + 680 Ω

Si-diode with 10 µF

Short Instructions
M 6003

Getting Started

Connect the instrument to the power line, depress the power push-button (at the right top, next to the screen).
Light-emitting diode indicates operating condition. **Case, chassis and measuring sockets are connected to the protective line conductor (protection class I).**
Do not depress any other pushbutton. **TRIG.** selector switch to **AC**.
Depress **LEVEL** knob.
DELAY sliding switch to **NORM.**, **HOLD-OFF** control to right stop.
Adjust INTENS. control for medium brightness.
Center trace on screen using **X-POS.** and **Y-POS. I** controls.
Then focus trace using **FOCUS** control.

Operating Mode Vertical Amplifiers

Channel I: **All** pushbuttons in Y-Section released.
Channel II: **CH II** pushbutton depressed.
Channel I and II: **DUAL** pushbutton depressed.
Alternate or chopped channel switching optionally with **ADD/CHOP.** bushbutton.
Signals < 1 kHz with **ADD/CHOP.** pushbutton depressed.
Channels I and II (sum): Depress **I + II (ADD/CHOP.)** pushbutton only.
Channels −I +II (difference): Depress **I/II (ADD/CHOP.)** and **CH I INV.** pushbuttons only.

Trigger Mode

Select the trigger mode with **LEVEL** control (push and/or pull):
PEAK – Automatic peak value triggering. **NORMAL** – normal triggering.
Trigger edge direction: Select with **SLOPE +/–** pushbutton.
Internal triggering: Select channel with **I/II** pushbutton.
Internal alternate triggering: Depress **ADD** pushbutton.
External triggering: Depress **EXT.** pushbutton; synchronous signal (50 mV_{pp} – 0.5 V_{pp}) to **EXT. TRIG.** connector.
Line triggering: **TRIG.** selector switch to **LINE**.
Select trigger coupling with **TRIG.** selector switch **AC-DC-HF-LF.**
Trigger frequency range: **AC** and **DC** to 1 MHz, **HF** above 1 MHz, **LF** below 1 kHz.
Video signal mixtures with line frequency: **TRIG.** selector switch to **AC** (possibly to **DC**).
Video signal mixtures with frame frequency: **TRIG.** selector switch to **LF**.
Pay attention to trigger indicator: Lamp next to **TRIG.** selector switch.
Single sweep: With **SINGLE** and **RESET** pushbuttons. Readiness indicator: **READY** light-emitting diode.

Measuring

Connect test signal to **CH. I** and/or **CH. II** vertical input connector.
First, compensate attenuator probe using built-in square-wave generator **CALIBRATOR**.
Select **AC** or **DC** input coupling.
Adjust required display height of signal with attenuator switch.
Y-expansion X 5: Pull Y-vernier control, **pull X 5.**
Pay attention to Y-overscan indication (**OVERSCAN**).
Select time coefficient on **TIMEBASE** switch.
Adjust trigger point with **LEVEL** control.
Eventually **trigger** complex or aperiodic signals with increased **HOLD-OFF** time.
Amplitude measurement with Y-vernier control to right stop C.
Time measurement with time vernier control to right stop **C.**
X 10 expansion: **pull X 10** control.
External horizontal deflection (X-Y operation) with **X-Y** pushbutton depressed (X-input: **CH. II**).
Expansion of a portion with **sweep delay:**

Position **NORM:**	Normal operation without sweep delay (DELAY lamp dark).
Position **SEARCH:**	With **DELAY** range switch and **VAR 10:1** DELAY vernier control select point of interest (DELAY lamp flashing).
Position **DELAY:**	Select length of portion and/or expansion by rotating **TIMEBASE** switch clockwise (DELAY lamp constantly illuminated).

Component Tester

Depress **Component Tester** pushbutton. Connect both component terminals to CT and ground jacks.
In-circuit test: Disconnect circuit from voltage and ground (floating). Pull out power plug, remove all connections to M 6003 (cable, probe), only then start testing.

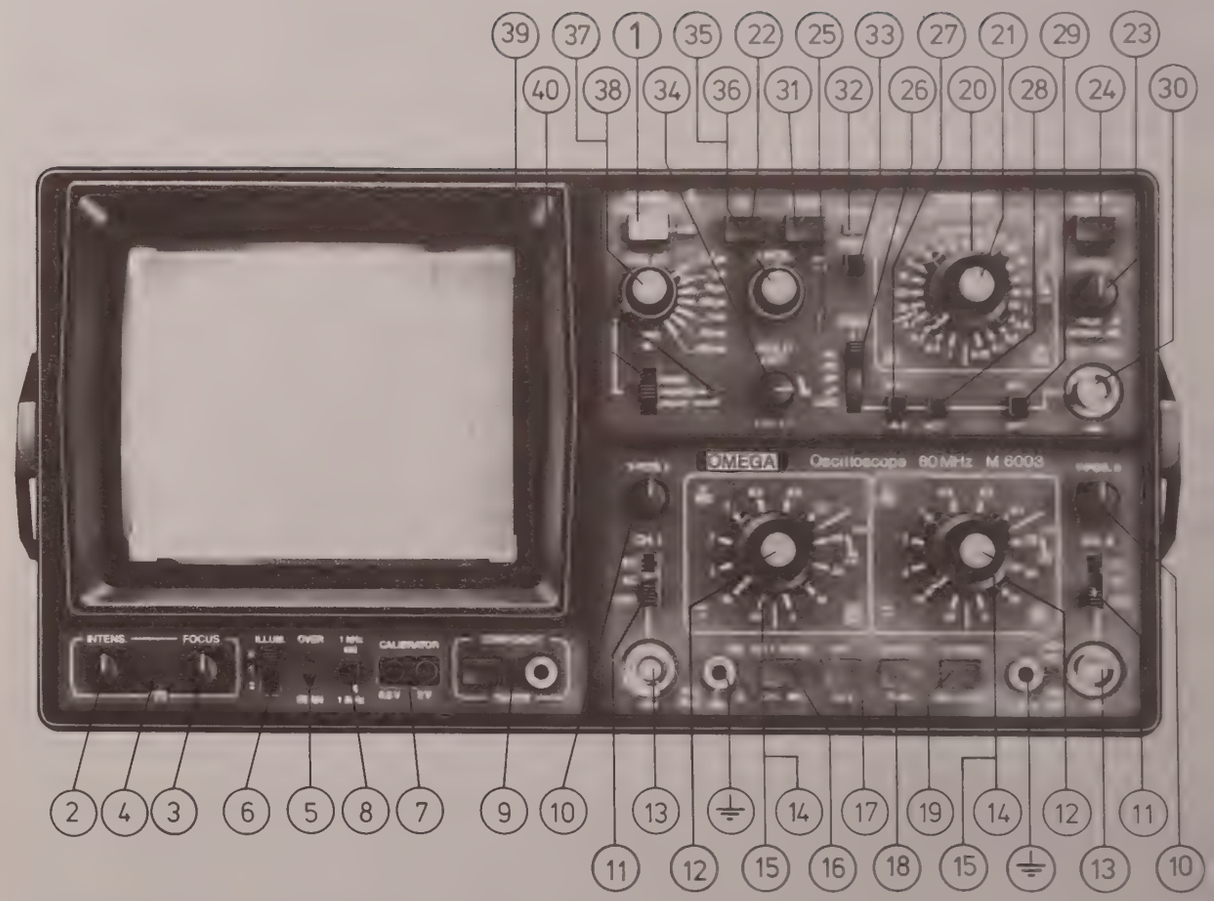
Operating Controls M 6003 (Brief description — Fig. 5, Front View)

	Operating Control	Function
❶	**POWER ON/OFF** (pushbutton switch and LED indicator)	Line master switch, light-emitting diode indicates operating condition.
②	**INTENS.** (rotary button	Intensity adjustment of cathode ray.
③	**FOCUS** (rotary button)	Control to adjust sharpness of cathode ray (must be readjusted with changed intensity).
④	**TR** trimmer potentiometer (adjustment with screwdriver	Trace rotation. Used to compensate for the earth's magnetic field. Makes for horizontal trace position.
⑤	**OVERSCAN** (LED indicators)	Direction indicators — illuminates when trace passes vertical screen limits.
⑥	**ILLUM.** 0,1,2 (3 position sliding switch)	Graticule illumination — 3 positions, 0 ═ OFF; 1 ═ dim; 2 ═ bright.
⑦	**CALIBRATOR 2V-0.2V** (test sockets)	Square-wave output of calibrator, 2 V_{pp} and/or 0.2 V_{pp} (frequency setting ⑧).
⑧	**1 kHz — 1 MHz** (pushbutton)	Frequency of calibrator output pushbutton released ═ 1 kHz; pushbutton depressed ═ 1 MHz.
⑨	**COMPONENT TESTER** (pushbutton and 4 mm socket)	With pushbutton depressed, the instrument operates as component tester. Connect the component under test to the test socket and to a ground socket.
⑩	**Y-POS. I, Y-POS. II** (rotary switch)	Adjustment of vertical position of trace for Channel I and II.
⑪	**CH. I** — DC, AC, GND **CH. II** — DC, AC, GND (sliding switch)	Switch for input signal coupling, Channel I and II. DC ═ direct coupling, AC ═ coupling via a capacitor, GND ═ oscilloscope input shorted; input signal open.
⑫	**Y-AMPL. I (II)** Y-gain (12-position rotary switch)	Calibrated input attenuator. Determines the Y-gain factor in 1-2-5 sequence and indicates the scale factor (V/DIV, mV/DIV).
⑬	**CH. I, CH. II** (BNC sockets and separate ground sockets)	Signal inputs — Channel I (left) and Channel II or horizontal X-input (right). Input impedance 1 MΩ ‖ 28 pF.
⑭	Variable Y attenuation (rotary button)	For vernier control of Y-amplitude (Channel I or II). Attenuates the input signal by a factor of 2.5 max. (Left stop). For amplitude measurement, it must be set to C (Right stop).
⑮	**pull X 5** (push-pull switch)	Increases Y-sensitivity of Channel I and II by the factor of 5. Max. input sensitivity at position 5 mV/DIV and button pulled ═ 1 mV/DIV.
⑯	**CH I INV.** (pushbutton)	When depressed, reverses polarity of Channel I. (in conjunction with ADD/CHOP ═ I+II-pushbutton ⑲ ═ difference display).
⑰	**CH I/II** (pushbutton)	Single channel operation (DUAL pushbutton not depressed): Pushbutton not depressed ═ display of Channel I, pushbutton depressed ═ display of Channel II.
⑱	**SINGLE DUAL** (pushbutton)	Selects SINGLE CHANNEL mode (pushbutton not depressed) or DUAL CHANNEL mode (pushbutton depressed.
⑲	**ALTERN/ADD/CHOP** (pushbutton)	**Dual channel mode** (DUAL pushbutton depressed): Channel switching altern. or chop. Signals <1 kHZ with pushbutton depressed. With DUAL pushbutton not depressed displays the sum of Channel I and II (ADD/CHOP pushbutton depressed).
⑳	**TIMEBASE** (23-position rotary switch)	Selects trace speed. 23 calibrated positions —1 s/DIV to 0.05 µ/DIV.
㉑	Variable timebase control (rotary switch)	For vernier control of timebase. Reduces trace speed by at least the factor of 2.5 (left stop). Must be set to C position for time measurement (right stop).
㉒	**X-Y** (pushbutton)	X-Y operation. With X-Y pushbutton depressed, internal timebase switched off. External horizontal deflection via CH II input. **Caution: Danger of baking with missing timebase.**
㉓	**LEVEL — PEAK/NORMAL** (rotary knob and push-pull switch)	Automatic peak value triggering (button depressed) or normal triggering (button pulled). Trigger threshold adjustable by rotating the button.
㉔	**SLOPE +/—** (pushbutton)	Signal display starts with rising edge (pushbutton not depressed) or with falling edge (pushbutton depressed).
㉕	**TRIG.** (LED indicator)	Indicator lights when timebase is triggered.
㉖	**TRIG.** AC-DC-HF-LF-LINE (sliding switch)	Selection of trigger coupling. AC and DC to 1 MHz, HF above 1 MHz, LF below 1 kHz. LINE for triggering with line frequency.
㉗	**TRIG. I/II** (pushbutton)	Triggering from Channel I (pushbutton not depressed) or Channel II (pushbutton depressed).
㉘	**ALT.** (pushbutton)	Alternate triggering from Channel I and Channel II. ALT. pushbutton depressed.
㉙	**EXT.** (pushbutton)	Triggering via external signal. Signal input via EXT. TRIG. socket ㉚.
㉚	**EXT. TRIG.** (BNC connector)	Input for external trigger signal. Pushbutton ㉘ depressed.
㉛	**SINGLE** (pushbutton)	Single sweep display (pushbutton depressed). Trace triggering with next following trigger pulse.
㉜	**READY** (LED indicator)	LED indicator lights when ready for single sweep operation; goes out after triggering.
㉝	**RESET** (pushbutton; without stop position)	Restores operating condition for single sweep (after triggering).
㉞	**HOLD-OFF** (rotary button)	Vernier control for time interval between two sweep signals. Basic setting ═ right stop.
㉟	**X-POS.** (double rotary button)	Adjust the horizontal trace position: large button ═ coarse adjustment, small button ═ vernier adjustment.
㊱	**pull X 10** (push-pull switch)	Expansion of X-axis by a factor of 10 (small rotary button pulled). Max. resolution ═ 5 ns/DIV.
㊲	**DELAY** (8-position rotary switch)	Coarse adjustment of sweep delay time. Operative only with the DELAY sliding switch set to positions SEARCH and DELAY ㊴.
㊳	**DELAY** (rotary button; small button)	Vernier adjustment of delay time. 20-turn helical potentiometer. Same function as ㊲.
㊴	**DELAY** NORM, SEARCH, DELAY (sliding switch)	Operating modes for DELAY operation, 3 positions: NORM ═ OFF; SEARCH ═ range adjustment for delay time; DELAY ═ timebase delay. TIMEBASE can be used for expansion.
㊵	**DELAY** (LED indicator)	Indicator for DELAY mode: OFF ═ position NORM, flashing ═ SEARCH and illuminated ═ position DELAY.

Controls located underneath the instrument:

㊶	DC-Balance (trimmer potentiometer)	For adjustment of the DC balance. Screwdriver adjustment.

(Figure 5) **Front View**

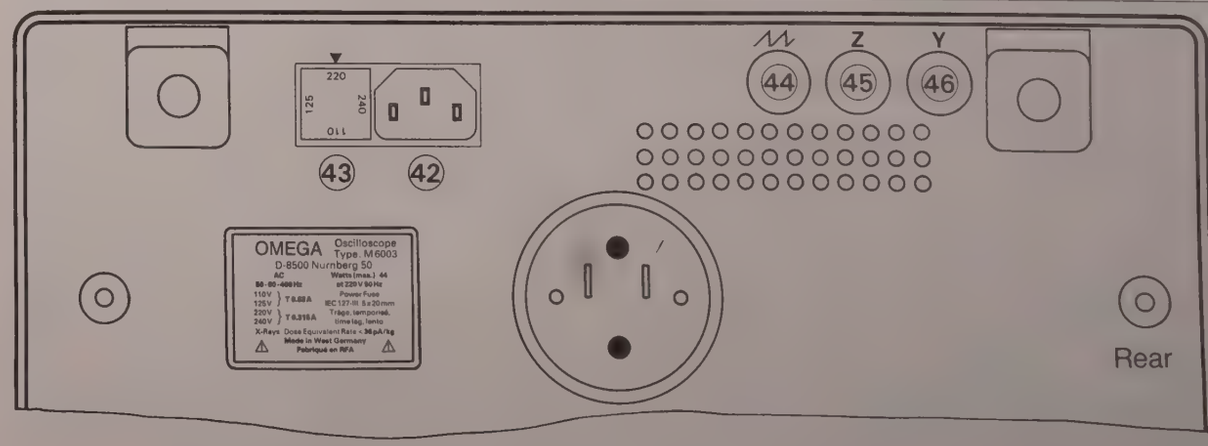


Rear

Outputs and inputs on the rear of the instrument:

	Operating Controls	Function
㊷	Power cord connector	For appliance connector of line supply cord.
㊸	Line voltage selector	For selection of operating voltage. Fuse holder at the same time.

	Operating Control	Function
	BNC sockets:	
㊹	/V\-output	Output for sawtooth voltage of generator (approx. 5 V_{pp}).
㊺	Z-input	Input for trace modulation (trace on or blanked).
㊻	Y-output	Output of the vertical amplifiers, e.g. for connection of frequency meters.



Rear

Test Instructions

General

These test instructions are intended as an aid for checking the most important characteristics of the M 6003 at regular intervals without the need for expensive test equipment. Resulting corrections and readjustments inside the instrument, detected by the following tests, are described in the Service Instructions. They should only be performed by qualified personnel.

As with Getting Started, care should be taken that all knobs with arrows are set to the calibrated positions. None of the pushbuttons shall be depressed, **LEVEL** control to **PEAK** (depressed), **TRIG.** selector switch to **AC**, DELAY skiding switch to **NORM.** It is recommended to switch on the oscilloscope about 15 minutes prior to starting the test.

Cathode-Ray Tube, Intensity and Focus, Linearity, Raster Distortions

Normally, the cathode-ray tube of the M 6003 has a very good brightness. Any reduction of this brightness can only be judged visually. A certain out-of-focus condition in the edge zone of the screen must be accepted. This is due to the CRT characteristic. Decreased brightness may be the result of reduced high voltage. This is easily recognized by the greatly increased sensitivity of the vertical amplifier. The setting range for maximum and minimum brightness must be such that the beam just disappears before reaching the left hand stop of the **INTENS.** control, while with the control at the right hand stop the focus and the trace width are still acceptable. **With maximum intensity the timebase fly-back must on no account be visible. Also with the X-Y pushbutton depressed, it must be possible to completely blank the trace.** It should be noted that with wide variations in brightness, refocusing is always necessary. Moreover, with maximum brightness, "pumping" of the display shall not occur. If the latter occurs, it means that the high voltage supply is instable. The potentiometers for high voltage, minimum and maximum intensity are only accessible inside the instrument (see Adjusting Plan and Service Instructions).

Certain linearity tolerances and raster distortions are also due to the manufacturing process of the CRT. They must be accepted as long as the limit values specified by the manufacturer are not exceeded. Here, too, the marginal zones of the screen are affected. The same is true for tolerances of axis and center deviation. All of these limit values are strictly supervised in production. Selection of a cathode-ray tube without any tolerances is practically impossible (too many parameters).

Astigmatism Check

Check whether the horizontal and vertical sharpness of the traces are equal with the same **FOCUS** setting. This is best seen by the display of a square-wave signal of higher frequency (approximately 1 MHz). A spot display is another way of checking. With the Y-input (**GND** position) disconnected and the **X-Y** pushbutton depressed, repeatedly vary the **FOCUS** control around the focusing point. The shape of the spot (not its size), whether round, oval or rectangular, must stay the same at the right and left of the focusing point. A potentiometer of 50 kΩ is provided inside the instrument for the correction of astigmatism (vertical sharpness). (See Adjusting Plan and Service Instructions).

Symmetry and Drift of the Vertical Amplifier

Both of these characteristics are substantially determined by the input stages. **Checking and correction of the DC balance shall be performed as described in the Operating Instructions.**

Certain information on the symmetry of Channel I and the Y final amplifier is obtained by inverting (depress **INVERT I** pushbutton). The vertical trace position may change by about 5 mm with sufficiently good symmetry. A change of 1 DIV is just permissible. Larger deviations point to a change in the vertical amplifier.

A further check of the Y-symmetry is possible by checking the control range of the **Y-POS.** controls. A sine-wave signal of approximately 10 to 100 kHz is applied to the Y-input (signal coupling to **AC**). When the **Y-POS. I** control is then turned fully in both directions from stop to stop with a display height of approximately 8 DIV, the upper and lower portions of the trace that are visible should be of about the same height. Differences of up to 1 DIV are permissible.

Checking of the drift is relatively simple. About **10 minutes after switching on the instrument**, set the baseline exactly on the horizontal center line of the graticule. The trace position must not change by more than 5 mm during the following hour. Larger deviations generally result from different characteristics of the dual FETs in the input to the Y-amplifier. To some extent, fluctuations in drift are caused by offset current at the gate. It is too high, if the vertical trace position drifts by more than 0.5 mm when turning the appropriate attenuator switch through all steps without a signal being applied. Sometimes such effects occur after long periods of operation.

Calibration of the Vertical Amplifier

A square-wave voltage of **200 mV_{pp}** and/or **2 V_{pp}** is present at the output sockets of the calibrator. Normally they have a tolerance of 1 % only. If a direct connection is made between the 200 mV output socket and the input to the vertical amplifier (1:1 probe), the displayed signal in the **50 mV/DIV** position must be **4 DIV high** (vernier control of the attenuator switch to the right stop **C**; signal coupling **DC**). Maximum deviations of 1.2 mm (3 %) can just be accepted. If a **10:1 attenuator probe** is connected between the 2 V output socket and the measuring input, the same display height must result. With higher tolerances it should first be investigated whether the cause lies within the vertical amplifier itself or in the amplitude of the square-wave voltage. On occasions, it is possible that an interconnected attenuator probe is faulty of incorrect compensation, or its tolerances are too high. If necessary, calibration of the vertical amplifier is possible with an exactly known DC voltage (**DC** signal coupling). The trace position must then vary in accordance with deflection coefficient set.

With the vernier control on the attenuator switch set to the left stop, the input sensitivity is decreased at least by the factor of 2.5 in each switch position. If the attenuator switch is set to **50 mV/DIV**, it should be possible to decrease the height of the calibrator signal from 4 DIV to 1.6 DIV max.

The Y-expansion X5 increases the sensitivity by the factor 5. If the attenuator switch is set to **200 mV/DIV**, a set calibrator signal of 1 DIV in height shall change to a height of 5 DIV when the **pull X5** control is pulled.

Transmission Performance of the Vertical Amplifier

A check of the transmission performance is only possible with a square-wave generator having a fast rise time (max. 5 ns). The built-in CALIBRATOR is, thus, suited for this purpose (1 MHz). When using an external square-wave generator, the connection cable must be terminated directly at the vertical input to the oscilloscope with a resistor equal to the characteristic impedance of the cable. Checks should be made with 50 Hz, 500 Hz, 5 kHz, 50 kHz and 500 kHz (1 MHz). Thereby, the displayed square-wave signal must not show any overshoot, especially not at 500 kHz (1 MHz) and a display height of 4—5 DIV. However, the leading top corner of the pulse must not notably be rounded. At the specified frequencies neither ramp-offs, nor spikes or glitches must be visible at the top. Setting: deflection coefficient **5 mV/DIV**; signal coupling to **DC**; Y vernier control to calibrated position **C**. In general, no great changes occur after the instrument has left the factory so that this test must not normally be performed.

Of course, the quality of the transmission performance is not only dependent upon the measuring amplifier. The **input attenuator** connected in front of the amplifier is **frequency-compensated in each position**. Even small capacitive changes can reduce the transmission performance. As a rule, faults of this kind are most easily detected with a square-wave signal having a low repetition frequency (e. g. 1 kHz). If a suitable generator with max. 40 V_{pp} is available, it is recommended to check all positions of the input attenuator at regular intervals and, if required, readjust (adjustment according to the Adjustment Plan). For this purpose, a compensated **2:1 series attenuator** is also required, which must be matched to the input impedance of the oscilloscope; it can be made up locally. It is important that this attenuator is shielded. For local manufacture, the electrical components required are a 1 MΩ resistor (± 1 %) and, in parallel with it, a C-trimmer 3/15 pF in parallel with approximately 20 pF. On the one side this parallel circuit is connected directly to the vertical input **I** and/or **II**, and on the other side connected to the generator via a cable of as low a capacitance as possible. The series attenuator must be matched to the input impedance of the oscilloscope in the **5 mV/DIV** position (vernier control to **C**; signal coupling to **DC**; square tops exactly horizontal without ramp-off). Then, the shape of the square-wave shall be the same in each input attenuator position.

Operating Modes: SINGLE/DUAL, ADD/CHOP, I+II and X-Y Operation

When depressing the **DUAL** pushbutton, two traces must appear immediately. When actuating the **Y-POS.** controls, the trace positions should have no affect on each other. Nevertheless, this cannot be entirely avoided, even with fully serviceable instruments. If one trace is shifted across the entire screen, the position of the other trace must not vary by more than 0.5 mm max.

A criterion in chopped operation is trace widening and shadowing around the baseline in the upper or lower region of the screen. Normally, both must not be visible. Set **TIMEBASE** switch to **1 µs/DIV**; depress the **DUAL** and **ADD/CHOP** pushbuttons. Signal coupling to **GND**; **INTENS.** control to right stop; adjust **FOCUS** for optimum sharpness. With the two **Y-POS.** controls shift one of the traces to + 2 DIV, the other to − 2 DIV height from the horizontal center line of the graticule. Do not synchronize to the chopper frequency (1 MHz)! Release and depress the **ADD/CHOP** pushbutton several times. Trace widening and periodic shadowing must be negligible.

It is important to note that in the **I+II** (only **ADD/CHOP** pushbutton depressed) or **−I+II** mode (**CH I INV** pushbutton additionally depressed) the baseline can be shifted with **both Y-POS.** controls.

With X-Y operation (**X-Y** pushbutton depressed), the sensitivity must be the same in both deflection directions. Thereby, the two vernier controls should be at the right stop (**C**) and the **pull X10** magnification control depressed. When the signal of the built-in square-wave generator is applied to the input of Channel II, then, as with Channel I in the vertical direction, there must be a horizontal deflection of **4 DIV** (**50 mV/DIV** position).

The check of single channel display with the **CH I/CH II** pushbutton is not necessary. It is indirectly contained in the tests described above.

Triggering Checks

The internal trigger threshold is important. It determines the display height from which a signal will be stably displayed. On the M 6003, it should be at 3 to 5 mm. A still more sensitive triggering creates the risk of response to the interference and noise level, especially so when the sensitivity of the vertical input is increased with the **pull X5** vernier control. This can produce phase-displaced double displays. Alteration of the trigger threshold can only be made internally. Checks can be made with any sine-wave voltage between 50 Hz and 1 MHz with automatic triggering (**LEVEL** control depressed). Following this, it must be checked whether the same trigger sensitivity is also present with normal triggering (**LEVEL** control pulled). **LEVEL** adjustment must be made in both trigger modes. When depressing the **+/−** pushbutton, the start of the sweep must change from the positive-going to the negative-going edge of the trigger signal. At a display height of approximately 5 mm and a selected **HF** trigger coupling, the M 6003 must correctly trigger sine-wave signals up to 80 MHz internally.

For external triggering (**EXT.** pushbutton depressed), a voltage of at least 50 mV_{pp} (synchronous with the Y-signal) is required at the **EXT. TRIG.** socket.

Checking of TV triggering is possible with a video signal of any polarity. Only in the **LF** position of the **TRIG.** selector switch, reliable **triggering to frame frequency is possible. However, triggering to line** frequency is only possible in the **AC** (eventually **DC**) position. If a video signal is not available, TV triggering can be checked by using the line and the calibration frequency. When triggering to the line frequency, the **LF** position must not bear any influence on the triggering. However, the minimum signal voltage required for correct triggering must at least double when 1 kHz calibration signal is applied.

When triggering internally or externally with a **sine-wave signal without a DC component**, the display must not shift horizontally when changing the **TRIG.** selector switch from **AC** to **DC**. The basic requirement for this is a **correct DC Balance Adjustment** of the vertical amplifier input (see Operating Instructions).

In alternate dual channel mode, two different signals (e. g. line frequency and calibrator signal) must be reliably (internally) triggered, depending upon the position of the I/II and ADD. pushbuttons. In the dual channel chopper mode and the ADD. position selected, triggering must only be possible from Channel I, and the chopper frequency must not be displayed.

If both vertical amplifier inputs are AC-coupled to the same signal, and both traces are brought to coincide exactly on the screen in alternate dual channel operation (only DUAL pushbutton depressed), then no change in display must be noticeable in any position of the I/II and ADD pushbuttons, or when setting the TRIG. selector switch from AC to DC.

A check of the line triggering (50 to 60 Hz) is possible with a line-frequency input voltage (also harmonic or subharmonic with the TRIG. selector switch set to LINE. To check that line triggering does not fail with very small or large signal voltage, the input voltage should be approximately 1 V. The displayed signal height can then be varied at random by turning the respective input attenuator switch (with vernier control).

Timebase

Before checking the timebase verify that the trace is 10 DIV long. If not, it can be corrected with the potentiometer for the sweep amplitude (see Adjusting Plan). This adjustment should be made with the TIMEBASE switch set to the 5 µs/DIV mid-position. Prior to starting the check, set the time vernier control to C and the HOLD-OFF time control to X 1. The pull X 10 button shall be in pushed position. This condition should be maintained until the individual variation ranges are checked. Also check that the sweep runs from the left to the right. For this purpose, center the trace on the horizontal center of the graticule using the X-POS. control, and set the TIMEBASE switch to 1 s/DIV (only important after a change of the cathode-ray tube!).

If a precise marker signal is not available for checking the timebase, then an accuractely calibrated sine-wave generator may be used. Its frequency tolerance should not be greater than ± 1 %. The timebase accuracy of the M 6003 is given as ± 3 %; but as a rule it is considerably better than this. For a simultaneous linearity check, at least 10 oscillations that is, one cycle every DIV, should always be displayed. For precise determination, set the peak of the first cycle exactly behind the first vertical line of the graticule using the X-POS. control. Eventual deviation tendencies can be noted already after the first cycles.

The 20 and 10 ms/DIV ranges can be checked very precisely with 50 Hz line frequency. On the 20 ms/DIV a cycle is displayed every DIV, while on the 10 ms/DIV range a cycle is displayed every 2 DIV.

When regular checks of the timebase are frequently made on a larger number of oscilloscopes, the purchase of an oscilloscope calibrator is recommended. It also has a quartz-controlled marker generator which issues needle pulses for each time range at a 1 DIV spacing. It should be noted that Normal Triggering and LEVEL adjustment are useful means for triggering of such pulses (LEVEL knob pulled).

The following table shows which frequencies are required for the particular ranges.

1	s/DIV	—	1 Hz	0.1	ms/DIV	—	10 kHz
0.5	s/DIV	—	2 Hz	50	µs/DIV	—	20 kHz
0.2	s/DIV	—	5 Hz	20	µs/DIV	—	50 kHz
0.1	s/DIV	—	10 Hz	10	µs/DIV	—	100 kHz
50	ms/DIV	—	20 Hz	5	µs/DIV	—	200 kHz
20	ms/DIV	—	50 Hz	2	µs/DIV	—	500 kHz
10	ms/DIV	—	100 Hz	1	µs/DIV	—	1 MHz
5	ms/DIV	—	200 Hz	0.5	µs/DIV	—	2 MHz
2	ms/DIV	—	500 Hz	0.2	µs/DIV	—	5 MHz
1	ms/DIV	—	1 kHz	0.1	µs/DIV	—	10 MHz
0.5	ms/DIV	—	2 kHz	0.05	µs/DIV	—	20 MHz
0.2	ms/DIV	—	5 kHz				

When turning the time vernier control to the left up to the stop, then at least 2.5 cycles/DIV are displayed (pull X 10 button pushed; measurement at 5 µs/DIV). When the pull X 10 button is pulled, then one cycle is displayed every 10 DIV (± 5 %) only (time vernier control to C; measurement at 5 µs/DIV). The tolerance can easier be measured in the 50 µs/DIV position (one cycle per DIV).

With a test oscilloscope, check the sawtooth output voltage at the BNC socket marked, ⎓, located at the rear of the instrument. Set the test oscilloscope to a deflection coefficient of 1 V/DIV and to a time coefficient which is one step slower than that set on the oscilloscope to be tested. It should then be possible to see 2 and/or 2.5 cycles of a positive-going sawtooth with an amplitude of approximately 5 V_{pp}. No input voltage (and no trigger voltage) should be applied to the oscilloscope to be tested. The sawtooth voltage is applied to the test oscilloscope by means of a non-terminated 50 Ω BNC-BNC cable. At the same time, the X 1 — X 10 HOLD-OFF time setting can be checked. A quantitative measurement of the hold-off time variation is not possible without manipulation inside the instrument (unblanking pulse is smaller than the forward length of the sawtooth).

Sweep Delay

The sweep delay should have no effect on the display of the calibrator signal, when the DELAY sliding switch is set to NORM. At position SEARCH, it is possible to check the delay time by means of the length of the blanked trace. When switching to DELAY, the display jumps to the left exactly to the usual trace position; the display of the signal has regained its full horizontal length of 10 DIV.

On the entire adjustment range of the VAR 10:1 DELAY vernier control, the displayed waveforms must be shiftable without any jitter or intermittent blanking. This can be checked with a calibrator signal. Setting: Connect the calibrator socket (0.2 V/1 kHz) to CH. I input socket, input coupling DC, switch position 50 mV/DIV, TRIG. selector switch to AC, LEVEL control depressed (automatic triggering), TIMEBASE switch to 1 ms/DIV, do not depress any pushbutton. First, set the DELAY sliding switch to NORM. Now the calibrator signal is displayed with a display height of 4 DIV and approximately 1 cycle per DIV. Then switch to SEARCH, the DELAY lamp flashes. Set the rotary switch DELAY to the 1 ms range. Then rotate the VAR 10:1 DELAY vernier control until the left half of the display is blanked. The delay time is now 5 ms. After switching to DELAY, the display is again fully visible; the DELAY lamp lights continuously.

The display can now be expanded. For this purpose, turn the **TIME-BASE** switch from 1 ms/DIV to 1 **µs/DIV** to the right. The expansion is now thousandfold. With the DELAY vernier control, the nearest edge of the calibrator signal can be brought to the center of the screen and checked for the above mentioned criteria. With a thousandfold expansion, the display brightness generally needs to be increased (with **INTENS.** and **FOCUS** control). Larger expansions are quite possible; the limits are defined by the decrease in brightness and by generator jitter.

Component Tester

The instant the **Component Tester** pushbutton is depressed, a horizontal trace of **approximately 8 DIV in length** must appear when the **CT** socket is open. When connecting the CT socket to one of the ground jacks, a vertical trace of **approximately 6 DIV display height** must appear. The given dimensions have some tolerances. Among other things, they depend upon the line voltage.

Trace Alignment

The cathode-ray tube has a permissible angular deviation of ± 3° between the X deflection plane D1 D2 and the horizontal center line of the internal graticule. This deviation and the influence of the earth's magnetic field, which depends upon the orientation of the instrument, must be corrected by means of the potentiometer marked **TR** (at the left, below the screen). In general, the trace rotation range is asymmetrical. However, it should be checked whether the trace can be adjusted with the **TR** potentiometer somewhat sloping **to both sides** around the horizontal center line of the graticule. With the M 6003 in its closed case, an angle of rotation of ± 0.57° (1 mm difference in height per 10 DIV trace length) is sufficient for compensation of the earth's magnetic field.

Miscellaneous

Checking of the **Z modulation** at the socket marked **Z** on the rear of the instrument requires a relatively low-ohmic square-wave generator (max. 600 Ω, max. 5 V_{pp}). A square-wave generator having **negative** pulses to ground **cannot** be used. The generator must not deliver an offset DC voltage; zero balancing should at least be possible. A sine-wave generator can be used if it delivers an — if possible adjustable — output voltage of max. 10 V_{rms} = 28 V_{pp}. The magnitude of this voltage determines the bright/dark duty factor, but a 1:1 value is not quite reached with a sinusoidal voltage. Alternatively, an adjustable (external) power transformer sinusoidal voltage can be used for Z-modulation of the time line (without a signal at the Y-input). **Setting:** Time coefficient **10 ms/DIV, TRIG.** selector switch to **LINE**, automatic triggering (**LEVEL** control depressed), no pushbutton depressed, input coupling **GND**. With a line frequency of 50 Hz, 5 horizontal traces of each 1 DIV in length that are interrupted by 5 blanks of the same length are now displayed. With a line frequency of 60 Hz, the distances are reduced to 8.3 mm; the number of traces and gaps increase to 6. A coarse check of the function of the Z-modulation can be made by shorting the Z socket. The baseline must then be blanked completely.

A check of the **Y-output** (Y socket at the rear of the instrument) is possible on the screen in dual channel mode with the aid of the calibration signal. For this purpose, connect the calibrator socket (**0.2 V/1 kHz**) directly to the vertical input of **CH. I** and the Y-output of the vertical input of **CH. II** by means of a BNC cable and a 50 Ω termination. **Setting: CH. I** attenuator switch to **50 mV/DIV, CH. II** attenuator switch to **0.1 V/DIV**, input coupling of **CH. I** to **DC** and input coupling of **CH. II** to **GND**, time coefficient **0.5 ms/DIV**, automatic triggering (**LEVEL** control depressed), **TRIG.** selector switch to **AC**, no pushbutton depressed. Now the square-wave signal is visible with **4 DIV** display height. With **Y-POS. I** control, the square-wave tops are adjusted to ± 2 DIV from the horizontal center line of the graticule. Then, depress the **DUAL** pushbutton. Adjust the appearing second trace (without signal) with the **Y-POS. II** control to — 2 DIV. Then, switch the input coupling of **CH. II** to **DC**. Now, the signal of the Y-output appears with the same phase position as that of the calibrator signal of Channel I. Both the DC offset (e.g. + 0.8 DIV = + 80 mV) and the amplitude (e.g. 1.6 DIV = **0.16 V_{pp}**) of the output can be measured. The sensitivity is then 0.16 : 4 DIV = **40 mV/DIV**. Without a 50 Ω termination, the values are twice as high.

If a steadily variable power transformer is available, the **characteristics of the line voltage fluctuation** should absolutely be checked as well. Within a fluctuation of ± 10 %, referred to the line voltage selected on the voltage selector (rear panel), the display must not show any changes, neither in Y nor in X direction with normal operation of the oscilloscope.

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